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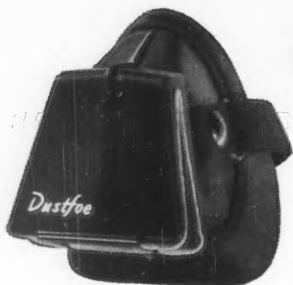
Hygiene

A S S O C I A T I O N

Journal

VOLUME 19, NUMBER 4

AUGUST 1958



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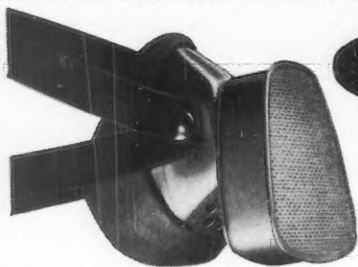
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President's Page



Financing an enterprise such as our American Industrial Hygiene Association without benefit of grants from government or benevolent foundations poses a problem: how to maintain and expand services to members without going into the red or increasing membership dues.

For the fiscal year ending May 31, 1958, AIHA expenditures exceeded income. This was due, not to administrative extravagances, but to substantial losses during 1957 on three issues of the old Quarterly and to an outlay of several thousand dollars for publication of our Industrial Noise Manual. Fortunately we had begun the year with a comfortable bank balance, only a part of which had to be used to make up the deficit.

In this new fiscal year there will be no losses on the new Journal and a fair share of the advance costs of the Noise Manual should return to us through sales. With reasonably good luck, income and operating expenses will be nearly the same. But there is no assurance of this and we must expect to publish within the year at least one more manual as a result of the hard work of our Technical Committees. A greater income would ease the strain and would guarantee that such worthwhile projects need not be delayed.

Individual and Industrial Associate membership fees currently account for more than 50% of Association income. (Journal subscriptions pass through our books to the publisher—there is neither net income nor expense.) Other important sources are the sale of Hygienic Guides and the annual Industrial Health Conference. Of all these sources Industrial Associate memberships hold the greatest promise of producing more income to meet AIHA operating expenses.

Hundreds of companies, large and small, employ no industrial hygienists yet they do have a need for the literature and services available through AIHA. One or more persons on their technical staffs would profit, and hence the companies would profit, by keeping up with industrial hygiene developments. In many instances these companies need merely to be informed that AIHA memberships are available to induce them to join. But most companies don't know because we do not have and never have had the funds for a large-scale publicity campaign. It is up to individual members to publicize Industrial Associate memberships. Tell your friends who may have an interest. Tell the companies with whom you do business. Refer them for detailed information to the nearest Industrial Associate Membership committeeman or to our Executive Secretary. You don't have to sell them—just tell them.

Kenneth W. Nelson

AMERICAN
Industrial Hygiene
ASSOCIATION *Journal*

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SOUND PROTECTION

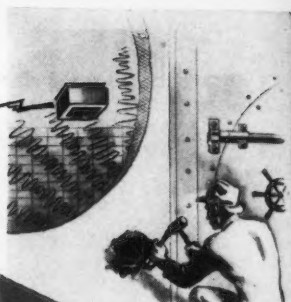


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PRICE: \$150

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The G-R Type 1555-A Sound-Survey Meter is used during installation of ADT Phonetalarm systems to determine the acoustical characteristics of vaults. In this way, each Phonetalarm installation is tailored to individual vault conditions, assuring positive burglar detection.

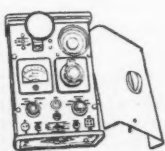
The Sound-Survey Meter is an easy-to-use, pocket-size meter for general purpose work where the refinements of more expensive sound-measuring equipment are not needed. Typical uses include:

- ★ Determining noise levels of appliances, machinery, and office equipment for product improvement.
- ★ Noise-control surveys in homes, offices, factories, and vehicles for protection against hearing damage.
- ★ Public-address-system installations in auditoriums, theaters, and restaurants.

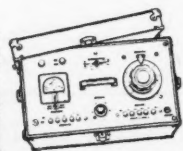
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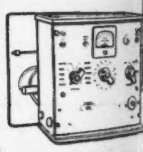
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The Adhesion and Removal of Particles Attached to Air Filter Surfaces*

RALPH I. LARSEN, Ph.D.

U. S. Department of Health, Education, and Welfare, Public Health Service,
Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

Introduction

PARTICULATE-LADEN air may be cleaned by passing it through fiber filters, electrostatic precipitators, cyclone separators, or other cleaning devices. To be effective, reentrainment of the particulates must not occur. Various means, such as oil-coating fibers or precipitator plates, are often employed to prevent such reentrainment.

Two basic mechanisms that cause particles to adhere to filter surfaces have been noted by various authors^{1,2}—adhesion due to a surface coating, such as viscous oil, and adhesion due to van der Waals intermolecular forces acting between a particle and a filter surface. Although these two mechanisms of adhesion have been recognized, there has been little quantitative information to indicate the strength of these forces and the variation in adhesive force with size and type of particle and filter. The purpose of the research described in this paper³ has been to determine the quantitative effect of several of the factors important to particulate adhesion and to determine the required air flow, fiber vibration, or other dislodging force necessary to remove particles from filter surfaces.

Measuring Adhesion

The force of adhesion of glass spheres to glass slides has been measured by McFarlane and Tabor⁴ using a sensitive "pendulum-type" apparatus for spheres as small as 500 microns in diameter. In order to measure the adhesive force for the microscopic particles of concern in air cleaning and air pollution control, a new method was devised for this study. This new

method uses a particle's own apparent weight, increased many fold by a centrifuge, to remove it from a surface. Theoretically, this method (Figure 1) may be used for the smallest particles and the dislodging force may be accurately determined. The centrifugal force is computed⁵ using an equation incorporating the radius of the centrifuge, the weight of the particle, and the angular velocity of the centrifuge. The maximum dislodging force which may be applied in practice is limited only by the maximum centrifugal acceleration of the centrifuge (Figures 2 and 3).

Several authors have noted the marked adhesion between solid surfaces when liquid is present between the surfaces. Bowden and Tabor⁶ have shown that the adhesion of a sphere to a plane surface (with a small amount of interposed liquid between the two surfaces) agrees with the theoretical value.

$$(1) \quad F_a = 2\pi T_s D_s$$

where F_a is the adhesion force perpendicular to the plane surface,

T_s is the surface tension of the interposed liquid, and

D_s is the diameter of the sphere.

The adhesive force determined for 133- and 166-micron spheres studied in this research indicates that the foregoing equation is valid for these sizes; it is also expected that the equation will hold for much smaller spheres, possibly in the one-micron range.

Equation (1) applies for a small amount of contact liquid between a sphere and a plane. In air cleaning practice, the particle often rests on a fiber rather than on a plane, and the amount of liquid between the particle and the fiber is often extensive rather than consisting of a minute point. The effect of fiber diameter and amount of contact liquid on the adhesive force has been determined theoretically in this study,

* Presented at American Industrial Hygiene Association Annual Meeting in Atlantic City, New Jersey, April 24, 1958. From *Fundamental Studies of Particle Dynamics and Adhesion*, a thesis, Harvard University, Department of Industrial Hygiene, Cambridge, Massachusetts (1957). The thesis may be borrowed from the Sanitary Engineering Center Library.

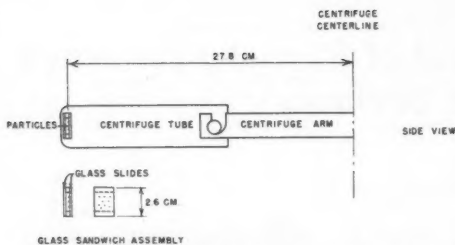


FIGURE 1. Particles being subjected to centrifugal force.

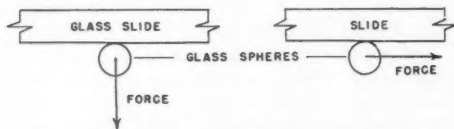


FIGURE 2. (Left) Centrifugal force applied normal to slide.

FIGURE 3. (Right) Centrifugal force applied parallel to slide.

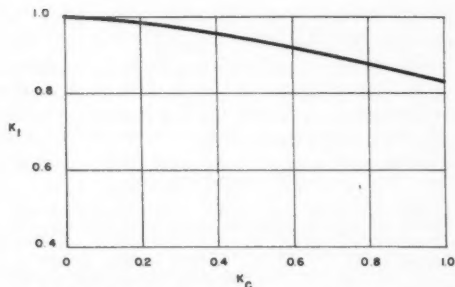


FIGURE 4. Effect of liquid contact diameter on adhesion of a sphere to a plane.

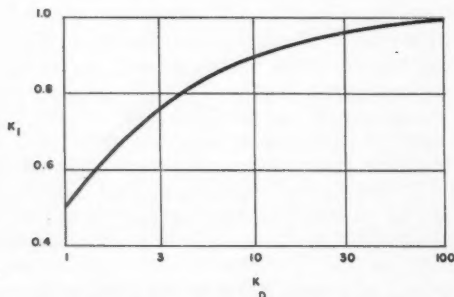


FIGURE 5. Effect of fiber diameter on adhesion of a sphere to a fiber.

see Equation (2), and has been confirmed experimentally.

$$(2) \quad F_a = k_1 2\pi T_s D_s$$

$$(3) \quad k_1 = \frac{\frac{k_d}{(k_c^2 + k_d^2)^{0.5}} + \frac{1}{(k_c^2 + 1)^{0.5}}}{\frac{2}{k_d} + 2}$$

where F_a is the adhesive force perpendicular to the fiber surface,

$$k_c = \frac{\text{liquid contact diameter}}{\text{sphere diameter}}, \quad \text{and}$$

$$k_d = \frac{\text{fiber diameter}}{\text{sphere diameter}}$$

In order to determine the effect of liquid contact diameter and fiber diameter, let us consider two situations. First, a sphere is resting on a fiber of infinite diameter (i.e., a plane) with varying amounts of liquid between the sphere and fiber (Figure 4). When the amount of liquid is finite, k_1 is 1; when the liquid contact diameter equals the sphere diameter, k_1 is 0.83. Second, a sphere is resting on a fiber of varying diameter with a finite amount of liquid between the sphere and fiber (Figure 5). When the fiber diameter is one hundred times the sphere diameter, k_1 is 1; when the fiber and sphere diameters are equal, k_1 is 0.5. Experimental runs have confirmed the theoretical evaluation of k_1 , see Equation (3).

Van Der Waals Adhesion

Several authors^{6, 7, 8} have discussed van der Waals intermolecular attraction of one molecule or body for another. This force not only holds materials together in one piece but also acts between two separate bodies, holding one to the other. In this study, the intermolecular attraction of a spherical particle for a plane or a fiber surface has been evaluated theoretically to be

$$(4) \quad F = \frac{6.57 D_s}{x^2}$$

where F is the adhesive force in dynes,

D_s is the particle diameter in microns, and

x is the closest distance from the particle to the surface in Angstroms. (1 Angstrom = 0.0001 microns.)

This "dry" adhesive force was not investigated by direct experiment, for water was apparently

adsorbed on the particles and fibers even at very low humidities. Also, it was not possible to determine the small distance, x , between the particle and fiber. Experiments did indicate, however, that at low relative humidities both van der Waals force and liquid adhesion were important, and that at high relative humidities, liquid adhesion was much stronger than van der Waals adhesion.

Removing Isolated Particles from Filter Fibers

Several important variables in the removal of particles from fiber filters are: (a) fiber diameter, (b) particle diameter, (c) particle location on the fiber, (d) fiber coating, (e) fiber vibration, and (f) air drag.

To determine experimentally the force required to move particles lodged on a fiber, particles of a given diameter were applied to glass fibers of 10- to 816-micron diameter and their location was observed under a microscope (Figure 6). The fibers were either dry or coated with a liquid. The fiber assembly was then held in an air stream of known velocity and the movement of particles was noted with a microscope. By knowing the theoretical flow pattern of air about the fiber, the air drag coefficient, and the velocity of air approaching the fiber, it was possible to determine the air drag force which moved the particles (Figure 7). The fiber under test was then placed in the centrifuge and centrifugal force was applied (Figure 8). The change in particle position after centrifuging was noted with a microscope. Knowing the angular velocity of the centrifuge, the radius of the centrifuge, and the diameter and density of the spherical glass particles, it was possible to determine accurately the force which moved the particles. The calculated air drag force acting on a particle was then compared with the known centrifugal force. The results of these experiments indicate good agreement between these two forces.

The movement of individual spheres on oil-coated fibers subjected to air flow was studied (Figure 9). The results indicate (Figure 10) that

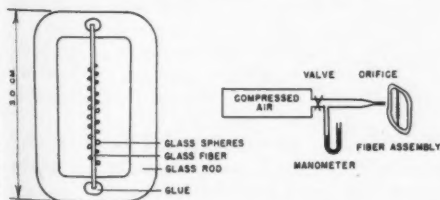


FIGURE 6. Glass fiber assembly

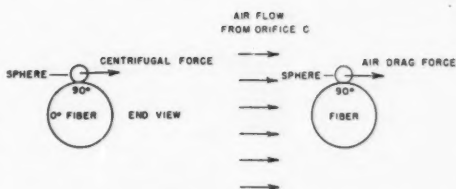


FIGURE 7. (Right) Air drag force applied to a particle lodged on a fiber.

FIGURE 8. (Left) Centrifugal force applied to a particle lodged on a fiber.

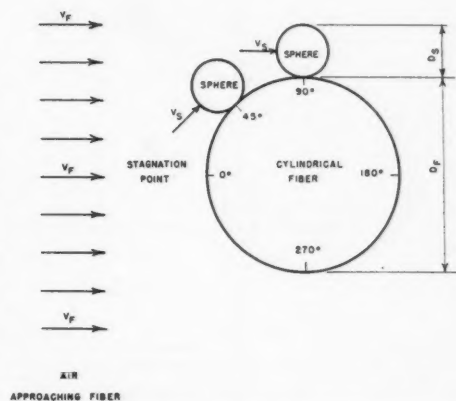


FIGURE 9. Velocity of air approaching spheres lodged on a fiber.

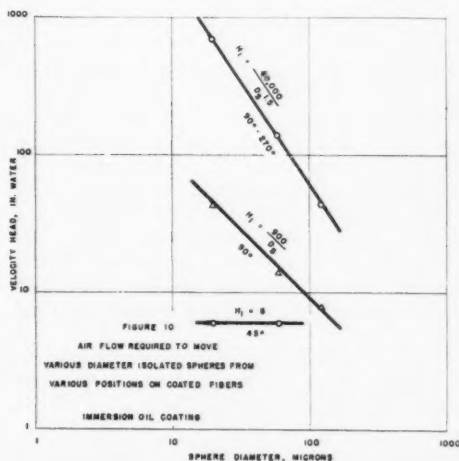


FIGURE 10

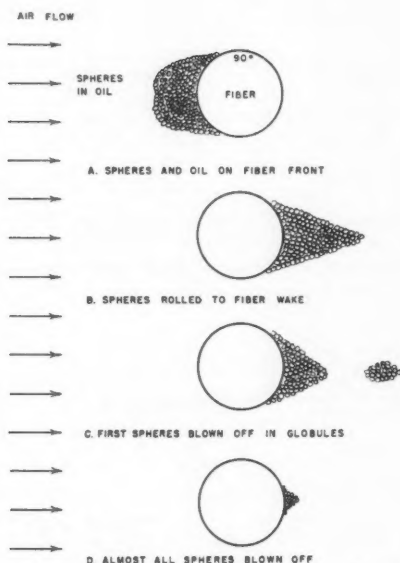


FIGURE 11. Blowing spheres from fibers heavily-coated with oil.

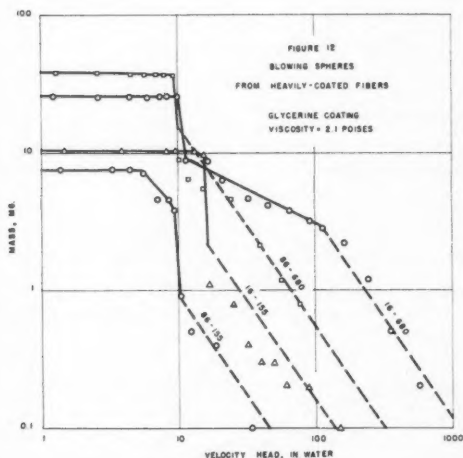


FIGURE 12

a velocity head of six inches of water is required to roll spheres from the 45-degree position to the fiber wake.

Further increase in air flow causes the spheres at the 90-degree position to roll to the fiber wake. The velocity head required is

$$(5) \quad H_1 = \frac{900}{D_s}$$

where H_1 is the air velocity head in inches of water, and

D_s is the particle diameter in microns.

Finally the air flow was increased until the particles were blown from the fiber wake. The velocity head required to accomplish this is

$$(6) \quad H_1 = \frac{60,000}{D_s^{1.5}}$$

Spheres from 12- to 120-micron diameter were studied. Fibers of 10- to 860-micron diameter were used. The movement of particles did not appear to be influenced markedly by variation in fiber diameter.

Removing Heavy Concentrations of Particles from Fibers

Commercial filters are usually operated for long periods, and would thus be expected to intercept and hold many particles. Removal of these heavy concentrations of particles has been studied. The removal of various diameter particles from various diameter fibers has been determined for uncoated, oil-coated, and water-coated fibers.

The stages in removing heavy concentrations of particles from a fiber heavily coated with oil are shown in Figure 11. A velocity head of four inches of water was required to roll the first spheres towards the rear of the fiber. A velocity head of ten inches of water was required to roll all of the spheres to the fiber wake (Figure 11B). The first spheres were dislodged completely, as globules, each containing many spheres, when the velocity head reached approximately eleven inches of water (Figure 11C).

Four experimental runs are shown using glass spheres of 16- and 86-micron diameter and glass fibers of 155- and 680-micron diameter (Figure 12). From these and other experimental runs the rate of mass removal is shown to be related to air flow velocity head as follows:

$$(7) \quad \frac{A_w}{A_f} = \frac{1330\mu}{D_s H^{1.5}}$$

where A_w is the cross-sectional area of the particles and the oil in the fiber wake, A_f is the cross-sectional area of the fiber, D_s is the particle diameter in microns, H is the air flow velocity head in inches of water, and μ is the oil viscosity in poises.

Plots of this general equation are shown as the dotted lines on Figure 12.

The relationship of variables in Equation (7) appears reasonable, for observation indicated

that: (a) the more viscous the oil, the less it was whipped about by air flow, and thus the better it was able to hold particles and prevent their removal; and (b) the larger the sphere diameter, the greater the relative roughness of the wake, and thus the greater the air drag force.

Probably the most important point to note from these experiments is that no particles were removed from the fibers at air flows such as are used in commercial filters (about 0.01 inches of water velocity head) and that air flow through commercial filters could probably be increased significantly before any blow-off of particles from oil-coated surfaces would be expected.

Particles held to a fiber coated with water behaved differently than particles held with oil. Evaporation left only point liquid contacts between particles, which then behaved as a single mass glued together by the water contacts. Extremely high velocity heads were required to remove such particles from a fiber (Figure 13), a head of 200 inches of water being required to remove half of the particles. Although high air velocities were required to remove the majority of particles, a few of the particles were dislodged at velocity heads as low as two and three inches of water.

Humidity is a major factor influencing the adhesion of particles to uncoated fibers (Figure 14). An air flow velocity head of 0.1 inches of water caused significant numbers of particles to be removed from a fiber in an atmosphere at 22 per cent relative humidity. When the relative humidity was increased to 40 per cent, ten times the velocity head was required to produce similar removal, indicating that the greater the rela-

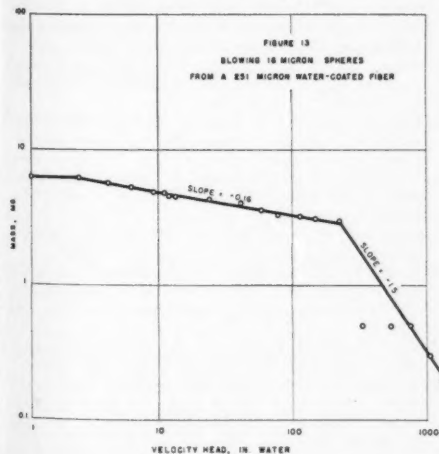


FIGURE 13

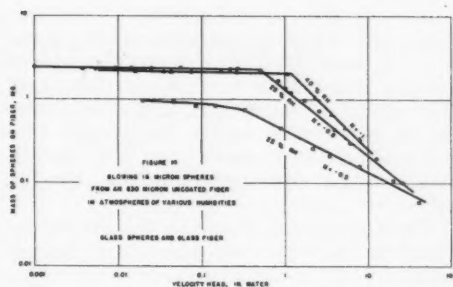


FIGURE 14

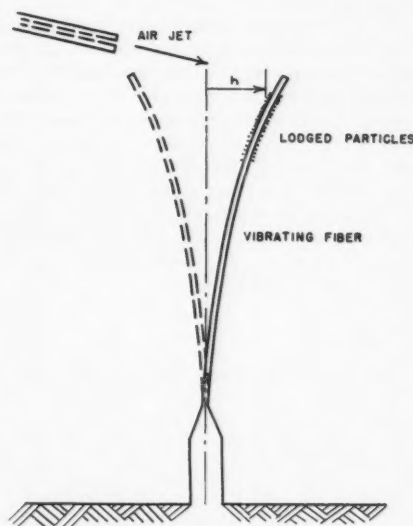


FIGURE 15. Vibrating fiber

tive humidity, the more tenaciously the particles adhere to the filter fiber.

Commercial filter fibers sometimes vibrate when subjected to air flow. Therefore the removal of particles by vibration was studied (Figure 15). Particles were placed upon an oil-coated fiber and an air jet was allowed to play on the top of the fiber, causing it to vibrate. The frequency and amplitude of vibration were determined and the dislodging force acting upon the particles was computed using Equation (8).

$$(8) \quad F_v = 2.06 \times 10^{-11} \rho_p D_p^3 h f^2$$

where F_v is the dislodging force in dynes, ρ_p is particle density in gm/cm³, D_p is particle diameter in microns, h is vibration amplitude in cm, and f is vibration frequency in cycles/second.

The dislodging force, Equation (8), was compared with the theoretical adhesive force, Equation (2), using 110-micron diameter glass spheres on 256- and 843-micron diameter glass fibers. The theoretical calculations were substantiated by the experimental results. The particles were not removed instantaneously, but little by little until most of them were dislodged after one minute of vibration.

These results should also be of value for determining the removal of particles from surfaces by rapping or shaking. If the maximum acceleration applied to particles by the rapping or shaking operation is known, the dislodging force can be calculated.

The removal of particles by bombardment from incoming particles was studied theoretically. It was concluded that bombardment will probably not remove particles from oil-coated fibers. If the incoming particles are greater than approximately five microns in diameter, they quite possibly will dislodge particles from uncoated fibers. It is also important to note that oil on the fiber does not necessarily indicate liquid adhesion; if the fiber becomes completely loaded, the additional particles adhere only because of "dry" adhesion.

Summary

The removal of various diameter glass spheres from various diameter glass fibers has been studied. Theoretical equations have been proposed to explain the force of adhesion to such surfaces. These equations have been confirmed experimentally. An air jet of controllable velocity was used to move glass spheres on glass fibers; at sufficiently high velocity heads the air flow caused the particles to be removed from the fiber. The air drag force was determined theoretically and checked against the actual dislodging force determined with a centrifuge.

The air flow required to remove isolated particles of various diameters from fibers of various diameters has been shown. Air flow velocity heads greater than ten inches of water are required to remove isolated particles from oil-coated fibers. Variation of fiber diameter does not appear to be an important factor.

The removal of heavy concentrations of particles from oil-coated fibers was determined. Particles are not blown from fibers until an air flow velocity head of approximately ten inches of water is reached. Above this point the tenacity with which particles adhere to the fiber is directly proportional to the viscosity of

the oil-coating and inversely proportional to the diameter of the particles.

The importance of relative humidity on the adhesion of dry particles to dry fibers was studied. Adhesion increases with increase in relative humidity. Ten times the air flow velocity head is required to remove particles at 40 per cent relative humidity as at 22 per cent relative humidity.

Particle removal by fiber vibration was studied. A theoretically derived equation expressing the adhesion of particles to vibrating fibers was determined and confirmed experimentally. Long vibrating times (approximately one minute) are required to remove particles from the fibers.

Results of this research indicate that commercial oil-coated fiber filters can be operated at much higher air flow rates before removal of particulates would be expected. The situation for dry fibers is not as clear however, for it appears that particles greater than five-micron diameter may dislodge other particles from a fiber by bombardment (assuming an air flow rate of 400 feet per minute).

Acknowledgments

An expression of thanks is extended to the United States Public Health Service and the Harvard Industrial Hygiene Department for providing the opportunity of undertaking this research. Professor Leslie Silverman's suggestion of the research topic and his continued interest and advice are deeply appreciated.

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Atmospheric Particulate Background in a Rural Environs*

FRANK E. ADLEY and WALLACE E. GILL

*Industrial Hygiene Operation, Health and Safety, Relations and Utilities Operation,
General Electric Company, Richland, Washington*

Outdoor air in rural areas is never completely free of suspended solids, whose presence depends mainly on local factors, such as meteorological conditions, vehicular traffic, and the physical disturbance of soil surfaces by cultivation. Knowledge of this natural atmospheric particulate background at Hanford is of importance in relation to the design requirements of ventilation air cleaning systems involving airborne solids which may pass through radioactive atmospheres and, in turn, become physically radioactive. Such information is also of value concerning the techniques for and the interpretation of certain types of air sampling.

Hanford is located in a desert region of southeastern Washington. Due to the low annual rainfall of about six inches, the highest order of natural vegetation is sagebrush except where irrigation has been introduced for agricultural purposes. The Hanford Plant site comprises about 600 square miles of desert country. This report presents a discussion of several pertinent factors associated with (1) the concentration of atmospheric dust as related to wind speed, (2) the relationship of the mass of airborne dust to its particle count, and (3) the settling rate and composition of suspended particulates. Air sampling and measurements were conducted over a period of nineteen months.

Measurements

WIND SPEED

Average wind speed measurements were made with a portable, totalizing, three-cup anemometer. The instrument was located six feet above ground level and about thirty feet from the air sampling station. Readings were taken simultaneously with the start and end of each air sampling test to permit correlation of wind speed and dust concentrations. In the preliminary phases of the study, wind speed data were

obtained from hourly readings recorded at the Meteorology Station about two miles away. It was felt that this distance imposed undesirable limitations on the interpretation of the wind speed data in relation to the findings from air sampling. Subsequently, the portable anemometer was used at the sampling station.

AIR SAMPLING

To determine the effect of wind on the concentration of dust, air samples of suspended particulate matter were collected adjacent to one of the laboratory buildings. Samples for gravimetric determinations were collected at a four-foot level by means of a hi-volume filter paper sampler utilizing Whatman No. 41 filter paper in a vertical plane. The volumetric flow rate was approximately 15 cfm. The length of sampling periods varied from five minutes up to several hours, depending on meteorological conditions and the estimated concentrations of suspended particulate matter. This method of air sampling produced integrated data which did not necessarily reflect the short-term fluctuations in dust concentrations that occurred during the sampling period.

Supplementary samples were obtained to determine the average monthly dust levels. A portable filter paper sampling head was located under a louvered shelter fifteen inches square and eighteen inches high. This protected the sampling unit from macroscopic particles of sand raised during periods of high winds. Whatman No. 41 filter paper was also used in this sampler, and the air flow was maintained at a constant rate throughout the sampling period. Sampling periods with this instrument ranged from one day to approximately one week, the length being determined by the filter loading.

All filter papers used for gravimetric analyses were subjected to a preliminary drying period of seven days in a convection oven at a temperature of 105° F. This temperature had been found sufficient to bring this paper to constant weight. Papers were then weighed to obtain

* Work performed under Contract No. W-31-109-Eng-52 between the Atomic Energy Commission and General Electric Company.

their tare weights. Following the collection of samples, the papers were re-dried according to the preliminary drying procedure and reweighed. CWS papers Nos. 5 and 6 were investigated but the components of these particular filtering media made it difficult to obtain constant weights.

Samples were also collected by Greenburg-Smith impingers to permit a determination of the degree of dustiness on a particle count basis. Distilled water was used as a collecting medium and particle counts were made according to standard dust counting techniques, although a Spencer Bright-Line Haemocytometer Cell was substituted for counting. Occasional impinger samples were evaporated to dryness to obtain the mass of collected solids.

Suspended Dust

EFFECT OF WIND ON MASS OF PARTICULATES

In an effort to determine the influence of wind speed on atmospheric dustiness, samples were collected over a wide range of wind speeds. A total of 146 air samples was collected and a similar number of wind speed readings were made over a period of seventeen months, commencing in January. The data are shown in

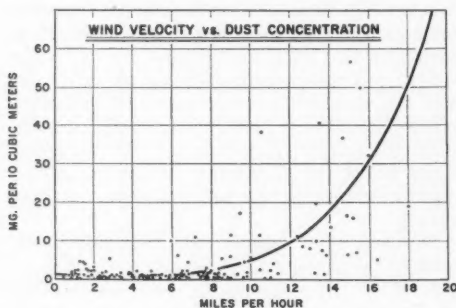


Fig. 1

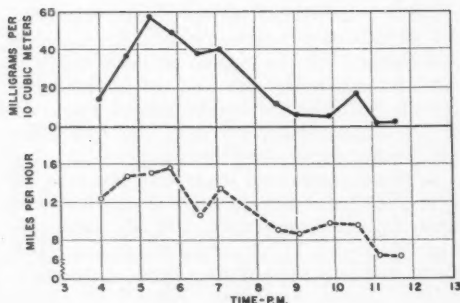


Fig. 2

Figure 1. From the graphical presentation, it is apparent that the general dust level remained practically constant up to about 7 miles per hour (mph). Samples which were collected during long periods of essentially still air conditions demonstrated a suspension of particulates having an average concentration of about 1.0 mg per 10 m^3 of air. This appeared to be the average background dust level at minimum wind speeds. The lowest concentrations encountered were slightly less than $0.1 \text{ mg per } 10 \text{ m}^3$. Occasional samples in the range of low wind speeds showed a distinct deviation in concentration from the average, which was believed attributable to local sporadic wind gusts and turbulence which raised and transported sufficient ground surface particulate matter to influence the samples. The effect of this factor became more pronounced with an increase in wind speed above 6 mph.

When wind speeds reached a level of about 10 mph, a more noticeable increase in atmospheric dust concentrations was prevalent. This level seemed to be just below that which raised visible dust from the surface of the ground. Occasional gusts of wind during these periods of elevated velocities were observed to have a more marked effect on the average dust concentrations. Strong gusts frequently raised and transported sand grains approximately 1 mm in diameter to the four-foot sampling level. This was observed microscopically in impinger samples. Above 10 mph a progressively wide variation existed in the individual dust concentrations as the wind speed increased. The dustiness at any particular speed in the higher ranges reflected a more pronounced effect by gusts which appeared to become more frequent with an increase in wind speed.

The data did not permit the determination of an exact velocity where visibly identified dust storms occurred. It was observed, however, that the level appeared to be approximately 15 mph. The maximum speed encountered for any individual sample during the study was 21 mph. This produced an accompanying average dust concentration over a period of twenty minutes of $146 \text{ mg per } 10 \text{ m}^3$.

In an effort to determine the rapidity of the change in atmospheric dustiness, as affected by variations in wind speed, a continuous series of air samples was collected at short intervals over a period of approximately eight hours when an increase in wind speed had been forecast. Samples were collected consecutively over the period with a hi-volume sampler about five feet above ground level. The results shown in Figure 2 demonstrate that the level of atmospheric dustiness follows with fair rapidity the changes in wind speed. It was evident that the

large particulate matter which was transported by high winds settled rapidly when the speed diminished. This was evident in three instances during the eight-hour period. Near the conclusion of this series of samples, the wind speed dropped from 9.5 to 6.4 mph within a thirty-minute period and was accompanied by a decrease in the dust concentration from 16 mg per 10 m^3 to 0.72 mg per 10 m^3 .

Samples obtained by long period sampling were collected consecutively when possible to permit a representative demonstration of the average monthly dust levels from February through July. Dust levels were found to vary from a minimum of 0.19 mg per 10 m^3 in February when the average wind speed was 5.8 mph to 1.7 mg per 10 m^3 in May with an average wind speed of 7.4 mph. The six-month average level of suspended particulate matter was approximately 1.1 mg per 10 m^3 . It was evident that when the average monthly wind speed attained levels of about 7 mph and greater, the dust concentrations increased markedly. This agrees favorably with the wind speed-dust concentration relationship shown in Figure 1.

EFFECT OF WIND ON PARTICLE COUNT

Atmospheric dustiness as portrayed on a particle count basis was demonstrated by a series of seventeen dust counts. Samples were collected by Greenburg-Smith impinger and counted by light-field microscopy as outlined in standard dust counting techniques. The concentrations varied from a minimum of 0.4 million particles per cubic foot (mppcf) of air at an average wind speed of about 2.2 mph to a maximum of 24 mppcf at 15.6 mph. Collected samples showed a large percentage of the total particles having a uniform size of about 0.9 micron or approximately that of the resolving power of the optical system employed. Accordingly, if the settling time for the standard counting technique was not adhered to rigidly, wide variations in counting results could be experienced. Particle size distributions were not included in this study. Although not a part of this investigation, previous air samples of outdoor air were obtained by thermal precipitation in this locality during periods of low wind speed and analyzed by electron microscopy. It was demonstrated that the size median of suspended particulates, on a particle count basis, was approximately 0.02 micron.

EFFECT OF WIND ON PARTICLE COUNT TO MASS RELATIONSHIP

The relationship between particle count and mass of suspended solids was also investigated. In some instances impinger samples were evapo-

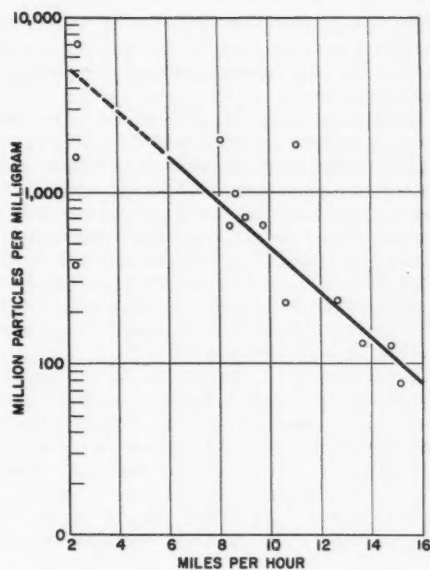


FIG. 3

rated to dryness and weighed. In other tests, the impinger and the hi-volume sampler were operated simultaneously, which permitted direct results on a particle count and weight basis, respectively. No significant difference was noted in the results obtained by the two methods. The relationship between the count and weight of suspended dust as affected by various wind intensities is presented in Figure 3. The counts reported therein were obtained through standard counting techniques. At the highest wind speeds encountered during this series of tests, the number of particles per milligram of dust was found to be about 10^6 . An inverse relationship was found to exist between the ratio of count to weight and average wind speed. A predominance of small particles created by the selective settling of the larger particles at wind speeds of about six miles per hour showed that a milligram of dust contained about 1.5×10^6 particles. Samples collected at minimum wind speeds contained many particles under 1 micron in diameter, the lower limit of resolution of the microscope system employed.

Settled Dust

COLLECTION METHOD

The rate of settling of atmospheric solids was determined at four stations. One was located on the roof of a building in a remote outer area in desert terrain; another was on a building roof

in a laboratory area outside of Richland; another was in an office in the same area; and the fourth, in a louvered attic space of a Richland residence.

Outdoor samples were collected in battery jars, six inches in diameter and twelve inches high. The jars were placed on four-foot tripods on the two roofs mentioned above. The collection jar in the remote area was 25 feet above ground level, and that on the roof in the laboratory area was 18 feet above ground level. The sample obtained in the office was collected about five feet above floor level in a 4.75-inch crystallizing dish. The fourth sample was also collected in a crystallizing dish.

A glycerol-water solution was placed in the bottom of the jars to a depth of about $\frac{1}{8}$ inch to avoid the possibility of collected dust being blown from the jars. This liquid was found to be satisfactory for holding all materials which

settled from the atmosphere and did not evaporate or freeze at the low temperatures encountered during the tests. The sampling jars and dishes were left undisturbed for a period of a month, after which the collections were washed out and replaced with fresh solutions.

The glycerol solutions and the contained samples were washed with distilled water from the collection devices and filtered through previously weighed Whatman low-ash paper. The papers were then dried and reweighed. The organic content of the settled solids was determined by placing the papers in a muffle furnace and burning off the combustible fraction.

SEDIMENTATION RATE

Twenty-four samples were collected from August through January. The quantities of settled solids, expressed as tons of material per square mile per month, are presented in Table I. The length of an equivalent month was thirty days.

The roof in the laboratory area consistently demonstrated the dustiest conditions. This building was adjacent to an unsurfaced driveway which had considerable vehicular traffic. The average rate of settled solids at this location was approximately 400 tons per square mile per month. The second highest dust-fall was at the other outdoor station on the roof in the remote area where there was comparatively less traffic. The average rate of deposition was 36

TABLE I
Settling of Airborne Particulates

Month	Sedimentation Rate (tons/mile ² /month)			
	Remote Area	Laboratory Area	Office	Richland Residence
August	32.2	226	1.6	5.8
September	15.3	207	0.6	4.6
October	119.0	207	2.6	2.5
November	33.	452	1.4	2.9
December	42.4	1100	8.6	36.1
January	3.6	222	2.5	12.4

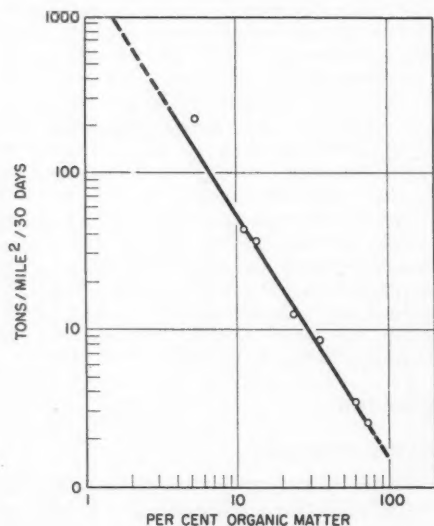


FIG. 4

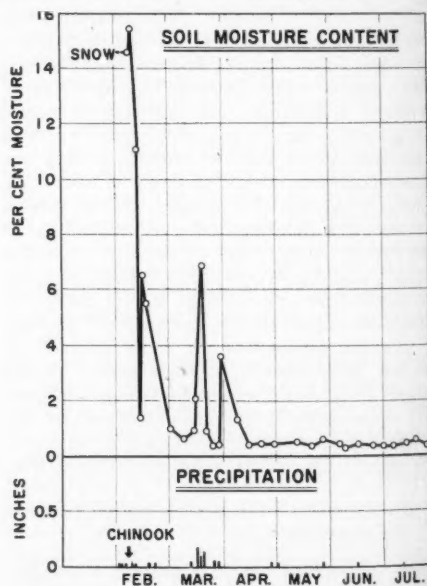


FIG. 5

tons per square mile per month. The maximum at this location occurred in October, at which time the dust-fall was 118 tons per square mile per month. The sampling station located in the attic space in Richland was sheltered by the roof and the dust was carried mainly by natural wind currents through the louvers at each end of the attic space. The average rate of deposition at this station was 11 tons per square mile per month. The lowest values were obtained from the office sampling station where the average settling rate for the six-month period was about three tons per square mile per month.

ORGANIC CONTENT

Organic determinations were made on eight individual monthly samples which represented a range in sedimentation rate from 2.5 to 1100 tons per square mile per month. It can be seen in Figure 4 that the organic content of the settled atmospheric dust varied inversely as the rate of dust-fall. The organic content ranged from 73.3 per cent at 2.5 tons per square mile per month to 3.8 per cent at 1100 tons per square mile per month. The Soil Sciences Unit reported that an analysis of surface soil from the locale of this study showed an organic content of only 2 per cent, the other major constituents, totalling about 90 per cent, comprised SiO_2 , Al_2O_3 , TiO_2 and Fe_2O_3 . It is felt that the inverse relationship indicated in Figure 4 can be attributed to the pick-up of grains of sand and other salient inorganic particulates from the ground surface during periods of increased wind speeds which raised the inorganic content of suspended solids at such times.

EFFECT OF SOIL MOISTURE

Soil samples for moisture content were secured from the top 1/4 inch of soil, excluding gravel and stone, in a ten-foot square plot of level un-

protected ground. The samples were weighed immediately, dried to constant weight and reweighed. Samples were taken weekly during periods of minimal precipitation. Following precipitation or the melting of snow, samples were collected with sufficient frequency to determine the rapid change in surface moisture content. In most instances, soil sampling was conducted coincidentally with air sampling and wind velocity measurements. Soil moisture content and precipitation are shown graphically in Figure 5.

An attempt was made to correlate the moisture content of the soil surface with the dust and wind conditions prevailing at any particular time. The data compiled were not sufficient to permit a satisfactory determination of any correlation which might have existed in these relationships. This was due largely to a dissimilarity of the soil moisture content in areas proximate to Hanford, so that the local soil moisture conditions were not necessarily representative of other areas which contributed to the atmospheric dustiness at the sampling location.

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HEALTH AND NUCLEAR TECHNOLOGY

WITH THE AID of a ten year grant from the Rockefeller Foundation a graduate program in the health aspects of nuclear technology has been established in the Graduate School of Public Health of the University of Pittsburgh. Two and three-year programs are offered leading respectively to a master's or doctoral degree. Physicians, engineers and physical scientists may be accepted for this training.

About 60 per cent of the time will be spent in didactic work and the remainder will be in clinical, field or research work. An extensive program of cooperation with several clinical facilities and varied nuclear installations has been arranged.

For detailed information of entrance requirements, courses, and fellowships write: Secretary, Graduate School of Public Health, University of Pittsburgh, Pittsburgh 13, Pennsylvania.

A New Technique for Fabric Filter Evaluation*

DAVID G. STEPHAN, PAUL T. BOHNSLAV, ROBERT A. HERRICK,
GEORGE W. WALSH, and ANDREW H. ROSE, JR.

*U. S. Department of Health, Education and Welfare, Public Health Service,
Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio*

Introduction

RESEARCH on air filtration has been conducted in the past primarily with bench-scale equipment. Collection efficiencies, aerosol deposition mechanisms, and fluid flow through porous media can be and have been studied in this way. Research on full- or pilot-sized air filtration equipment has been restricted, however, by a lack of adequate techniques for measuring filtration and fluid flow parameters in such units.

Information about rates of dust cake buildup and about filter velocities (average air flow in linear ft/min through a given cross section) at specific locations on a filter surface would make possible a more detailed understanding of the filtration process as it occurs in practice. From a series of measurements at selected locations on the surface of a filter, profiles could be plotted which would relate the mass of the dust cake and the filter velocity to position on the filter and which would demonstrate changes in these values with time through the progress of a filtration cycle. Information of this type would give insight into the actual operation of commercial-sized air filters and would provide important keys for the establishment of optimum design and operational standards.

For the purpose of implementing this new technique for fabric filter evaluation, two new instruments have been developed in the Air Pollution Engineering Laboratories of the Public Health Service. One of these, the "mass probe", allows determination of local filter cake masses and the other, the "filter velocity probe", allows concurrent determination of filter velocities through specific areas of a filter. While these instruments have been developed for laboratory use on full-sized tubular filter bags, they are certainly useable in the field and are adaptable for use with other types of air filtration equipment.

* For presentation to the 1958 Industrial Health Conference, American Industrial Hygiene Association, Convention Hall, April 24, 1958, Atlantic City, New Jersey.

The Mass Probe

In the last decade a new engineering tool has become available, primarily as a quality control device for many industrial operations. This tool, the so-called beta thickness gauge, has found widely publicized application on production lines, but its use as a research tool has not been so widespread. The beta thickness gauge (the name "thickness gauge" is actually a misnomer) operates on the principle that beta radiation is absorbed by matter; therefore the intensity of radiation passing through an object is a measure of the mass of that object. Such an instrument, applied to the determination of the mass of a filter cake, has several advantages: the principle of operation is relatively simple, it is potentially quite accurate, it is, and perhaps this is the most important, able to make a measurement without physical contact with the material being measured, and it is readily adaptable to field use.

ISOTOPE SELECTION

The choice of a radioactive source for such a probe involves a compromise among several desired properties. Ideally the source would: (1) have high penetrating power, (2) have high sensitivity (large change in transmitted radiation for a small change in absorber mass), (3) have a constant intensity (long half-life), (4) have no gamma radiation content, (5) be safe to use, (6) be cheap and readily obtainable, and (7) be available in a convenient physical form.

A table listing beta-emitters by energy and half-life is presented in the Radiological Health Handbook¹. Isotopes were successively eliminated from this list of possible sources by first establishing a minimum practical half-life of 150 days and a minimum beta energy of 0.3 Mev. The list of isotopes remaining was further narrowed to those given in Table I by applying the criterion of commercial availability.

Unfortunately, penetrating power (range) and sensitivity bear an inverse relationship to one another, thus dictating that an isotope having the lowest possible, but still adequate, range

TABLE I
Properties of Possible Beta Sources^{1, 2}

Isotope	Half-life	Maximum Beta Energy (Mev)	Half-thickness in Aluminum (grains/ft ²)	Maximum Penetration (grains/ft ²)	Range of Significant Gamma Energies (Mev)
Co ⁶⁰	5.27 y	0.31	122	1,140	1.17-1.33
Zn ⁶⁵	250 d	0.32	127	1,170	1.12
Cs ¹³⁷ , Ba ^{137m}	33 y	0.52	250	2,360	0.66
Ag ^{110m}	270 d	0.53	257	2,430	0.12-1.52
Sb ¹²⁵	2.7 y	0.62	318	3,070	0.11-0.64
Cs ¹³⁴	2.3 y	0.65	341	3,220	0.56-0.74
Kr ⁸⁵	9.4 y	0.70	377	3,540	
Cl ³⁶	4.4 × 10 ³ y	0.71	386	3,640	
Tl ²⁰⁴	3.5 y	0.76	422	3,930	
Pb ²¹⁰ , Bi ²¹⁰	22 y	1.17	765	7,000	0.05
Eu ¹⁵⁴ , Eu ¹⁵⁴	13 y, 16 y	1.90	1,545	12,800	0.09-1.40
Sr ⁹⁰ , Y ⁹⁰	19.9 y	2.18	1,915	15,000	
U ²³⁸	4.5 × 10 ⁹ y	2.32	2,090	16,300	0.05
Ce ¹⁴⁴ , Pr ¹⁴⁴	282 d	2.97	3,070	21,000	0.13
Ru ¹⁰⁶ , Rh ¹⁰⁶	1.0 y	3.53	4,075	25,400	0.51-2.41

* U²³⁸ α Th²³⁴ β Pa²³⁴ β U²³⁴

be chosen. From preliminary investigations it was learned that the maximum wall density encountered in the tubular bag filters to be studied will be on the order of 8000 grains/ft² (1 grain per ft² = 0.070 mg/cm²), but that most measurements will fall in the region below 2000 grains per ft². Because of the tubular configuration of the filters, however, penetration of the beta particles must be through a double layer of dust cake plus an air space. It is also necessary that even at the greatest wall density an appreciable amount of radiation penetrate the object to be measured. To assure this, the maximum penetration of the isotope's beta particles should exceed twice the maximum wall density to be measured by roughly 50 per cent. On this basis, it immediately becomes evident from the maximum penetration values listed in Table I, that Pb²¹⁰-Bi²¹⁰ is the logical choice for measurements of wall densities of 2000 grains/ft² and less, and that Ru¹⁰⁶-Rh¹⁰⁶, in spite of its gamma content and relatively short half-life, can be used for filter loadings up to 8000 grains/ft². Because of its lower gamma content, Ce¹⁴⁴-Pr¹⁴⁴ was considered as a possibility even though its range is slightly less than that desired, but the fact that Ru¹⁰⁶-Rh¹⁰⁶ was immediately available as a sealed source while Ce¹⁴⁴-Pr¹⁴⁴ could be supplied, on short notice, only in liquid solution clinched the final decision to use Ru¹⁰⁶-Rh¹⁰⁶.

SOURCE ACTIVITY REQUIRED

Having established the particular isotopes to be used, it becomes necessary to determine the source intensity required of each. The factors affecting this decision are (1) the accuracy of

measurement required, (2) the maximum allowable time for making the measurement, (3) the maximum count rate which can be metered by the available instruments, and (4) the physical spacing between source and pick-up tube. The levels chosen for each of these factors are as follows:

Required accuracy ±1% of wall density
Maximum time for measurement 30 seconds
Maximum count rate 300,000 counts/min
Source-to-pick-up tube distance 9 inches

Since the decay of a radioactive element is a zero-order reaction which follows the laws of probability, a statistical analysis may be used to determine the accuracy with which a measurement may theoretically be made. It is known that, for a normal distribution, approximately 95 per cent of all measurements will fall within $\pm 2\sigma$ (σ = standard deviation) of the mean; this 95 per cent confidence level was arbitrarily accepted. From the statistics of radioactive counting, where, N is the activity detected in cpm and t is the counting time in minutes,

$$2\sigma = \pm 2 \sqrt{\frac{N}{t}} \quad [1]$$

At a 95 per cent confidence level, to determine the air-gap count rate required to achieve a one per cent accuracy in one-half minute, the change in mass associated with a 2σ change in activity detected must be determined over the entire calibration interval. For example, at the minimum mass to be measured, 800 grains/ft² (twice

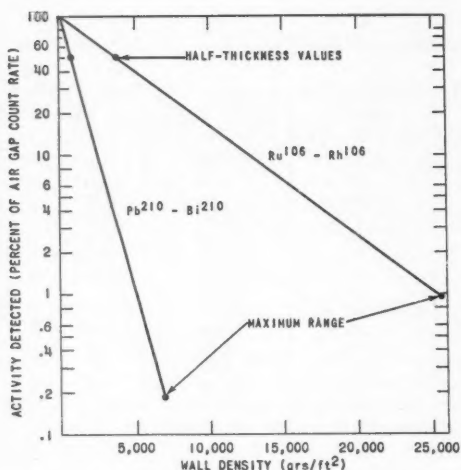


FIGURE 1. Theoretical calibration curves based on half-thickness values.

the approximate wall density of a clean filter fabric), a 2σ change in count rate must correspond to an 8 grains/ft² change in mass, i.e., one per cent of the mass being measured. From equations for the theoretical calibration curves in Figure 1, it can be seen that for Pb²¹⁰-Bi²¹⁰, 2σ must be equal to 0.4 per cent of the air-gap count rate. Expressing 2σ in equation [1] as a percentage at the air-gap count rate, N_0 ,

$$\frac{2\sigma}{N_0} \times 100 = \pm \frac{200}{N_0} \sqrt{\frac{N}{t}} = 0.4 \quad [2]$$

Again using the equation for the theoretical calibration curve, N at 800 grains/ft² equals 0.4844 N_0 . Hence, N_0 must be 242,000 cpm. Repetitions of this procedure over the range of wall densities to be measured show that, for the same theoretical accuracy, the largest air-gap count rate is required at the minimum wall density. Conversely, for a given source, percentage accuracy

of measurement increases with increasing wall density. A similar calculation for Ru¹⁰⁶-Rh¹⁰⁶ (at the minimum wall density to be measured with this source, 2000 grains/ft²) indicates that an air-gap count rate of 341,000 cpm will be required. This count rate is above that which can be metered, but with a filter of 2000 grains/ft² wall density between source and pick-up tube, the maximum rate which must be counted is below 173,000 cpm.

Finally, it is necessary to ascertain the actual source activity required, taking into consideration the 9-inch spacing between source and pick-up tube. In general,

$$\text{Source activity} = \left(\text{Correction for air absorption} \right) \left(\text{Correction for spacing} \right) \left(\text{Required air-gap count rate} \right)$$

The first factor to be considered is absorption of the air itself within the air gap. At an assumed density of 0.075 lbs/ft³, the air gap has an areal density of 400 grains/ft². In the case of Pb²¹⁰-Bi²¹⁰, Figure 1 shows that this will necessitate a correction factor of 1.43; for Ru¹⁰⁶-Rh¹⁰⁶ a correction factor of 1.04 is required. Secondly, because of the depletion of radiation flux with the square of the distance from the source, each square inch of surface nine inches from the source will receive only $(1/4\pi(9)^2) = (1/1018)$ of the emitted activity. Hence, when using a pick-up tube with a window area of 0.8 in.², the source activity must be,

Pb²¹⁰-Bi²¹⁰ source activity

$$= (1.43) \left(\frac{1018}{0.8} \right) (242,000) \text{ cpm} = 200 \text{ microcuries}$$

and,

Ru¹⁰⁶-Rh¹⁰⁶ source activity

$$= (1.04) \left(\frac{1018}{0.8} \right) (341,000) \text{ cpm} = 205 \text{ microcuries}$$

The cost of such sources is nominal; the Pb²¹⁰-Bi²¹⁰ and Ru¹⁰⁶-Rh¹⁰⁶ sources used were purchased for well under \$100 each.

PROBE DESIGN

The first probe constructed, using a Pb²¹⁰-Bi²¹⁰ source, is shown in Figure 2. The source, a disc 7/8-inch in diameter with appropriate shielding, is mounted in one end of a semi-circular Formica frame. A standard end-window GM tube is mounted diametrically opposite the source. Attached to the Formica frame directly above the

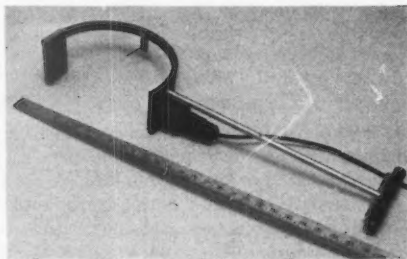


FIGURE 2. Pb²¹⁰-Bi²¹⁰ mass probe.

GM tube is an aluminum support rod. An adjustable stop, installed in the Formica frame at 90 degrees to the axis of measurement, aids correct centering of the probe around the filter bag.

The $\text{Ru}^{106}\text{-Rh}^{106}$ probe, Figure 3, is somewhat improved over its predecessor. As will be discussed later, probe calibration is sensitive to the positioning of the filter bag within the air gap. By mounting source and pick-up tube in separate holders and then joining them with one of a series of connectors, the possibility of variations in positioning is eliminated since source and GM tube are mounted as close together as clearance around the particular filter bag will allow. Further advantages of this type frame are: (1) potential accuracy is increased for filters less than 9 inches in diameter since count rate is increased by reduced air gaps, and (2) at the sacrifice of somewhat decreased accuracy, measurements may be made on filters with diameters exceeding 9 inches.

While the calculated activity for the $\text{Ru}^{106}\text{-Rh}^{106}$ source was 205 microcuries, a larger source, 350 microcuries is actually used. The air-gap count rate is reduced to approximately the calculated level by the use of a flat brass absorber over the source. The thickness of this absorber is decreased at approximately one-month intervals to compensate for the decay of the source. The 350-microcurie source being used will produce adequate activity for approximately eleven months with no reduction in accuracy.

It should also be pointed out that each probe is equipped with a protective cap which is placed over the source when the probe is not in use to eliminate unnecessary radiation exposure to personnel. Also, each GM tube operates with a cathode follower to minimize high voltage requirements and extend tube life.

SCALER

The counter used is a Model 163 Nuclear Instrument and Chemical Corporation Scaler which has been modified⁸ to produce automatic recording of detected activity on a standard millivolt recorder. This modification increases the maximum counting rate to 300,000 cpm by eliminating the mechanical register dial and permits the probe to be used by a single operator for a series of mass measurements in the shortest possible time.

CALIBRATION

Unfortunately, because of scatter of beta radiation as it passes through various materials, actual calibration curves for the mass probes differ significantly from the theoretical curves shown in Figure 1. The atomic mass of the ab-

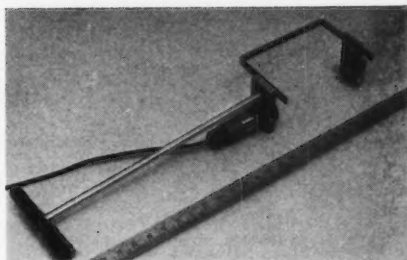


FIGURE 3. $\text{Ru}^{106}\text{-Rh}^{106}$ mass probe.

sorbing atoms and the absorber geometry (the physical shape of objects between source and pick-up tube) can both contribute to these differences, but in most cases, beta absorption is roughly independent of the nature of the absorber.⁴ It is therefore mandatory to calibrate such probes using the geometry that exists during measurements. The effect of geometry is shown rather dramatically in Figures 4 and 5, in the former the effect of flat vs tubular absorbers and in the latter the effect of asymmetrical positioning of probe around filter bag. As was pointed out earlier, the improved design of the $\text{Ru}^{106}\text{-Rh}^{106}$ probe minimizes the possibility of inadvertent positioning errors.

The specially designed calibration device used is shown in Figure 6. With this device, a 22-inch length of filter bag of the desired diameter is suspended from one pan of a double-pan balance. This bag is closed at the top and is sealed to the vertical inlet tube below with a thin polyethylene film. Dust is conveyed from the dust inlet chamber to the vertical inlet tube by a low volume, high velocity stream of compressed air.

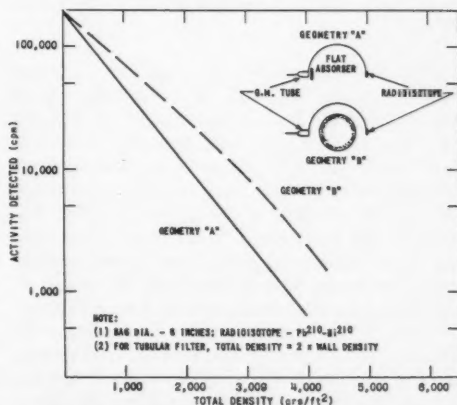


FIGURE 4a. Effect of absorber geometry on $\text{Pb}^{210}\text{-Bi}^{210}$ calibration curve.

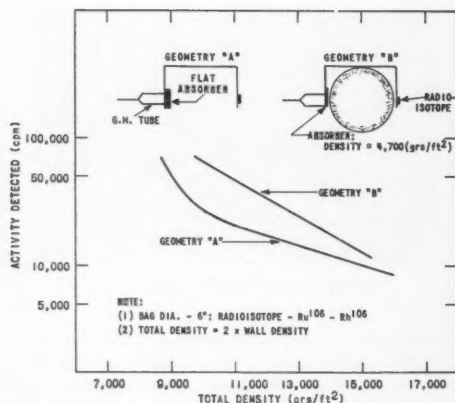


FIGURE 4b. Effect of absorber geometry on $\text{Ru}^{106}\text{-Rh}^{106}$ calibration curve.

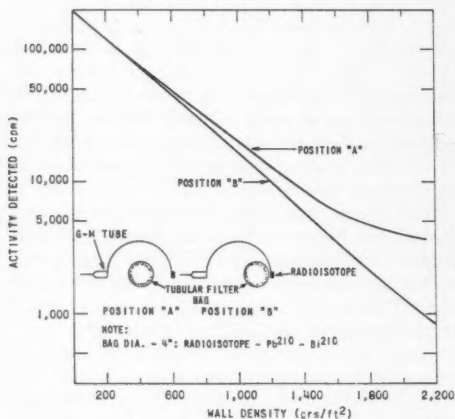


FIGURE 5. Effect of probe position on calibration curve.

In the inlet tube it is mixed with a much larger volume of air supplied by a variable speed blower and the dust-air mixture passes upward into the calibration filter. Readings with the mass probe are then taken at a series of filter loadings, each loading being determined directly by in-place weighing of the suspended filter. Because of the existence of "mass profiles" on even this short calibrating filter, mass probe readings are taken every four inches along the length of the filter and the results averaged to determine the exact wall density vs recorder reading relationship. Readings obtained represent, of course, the average density of opposite walls of the filter; calibration curves shown in Figure 7, therefore, are in terms of this average density.

Because of the 22-year half-life of $\text{Pb}^{210}\text{-Bi}^{210}$,

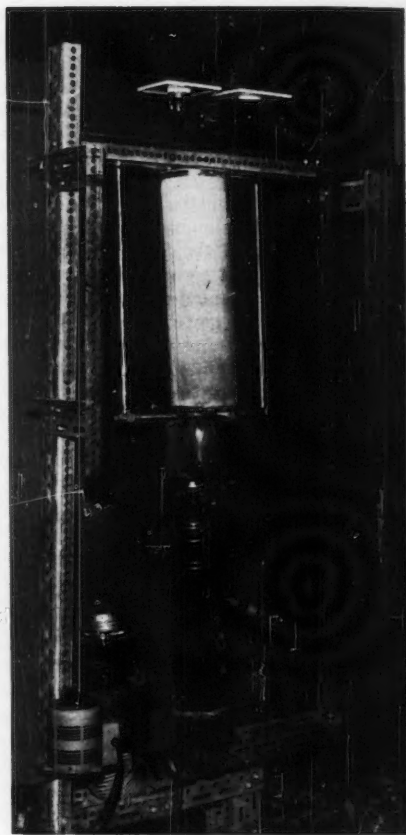


FIGURE 6. Mass probe calibration device.

the intensity of this source may be considered constant for any experimental program of reasonable length; the much shorter half-life of $\text{Ru}^{106}\text{-Rh}^{106}$, however, causes the intensity of this source to diminish at a rate such that a compensation technique must be employed. As mentioned previously, the air-gap count rate is adjusted at one-month intervals by reducing the thickness of the flat absorber over the GM tube window. Day-to-day compensations, however, can be made with the combination scaler-recorder unit being employed. Since, as is evident from Figure 1, calibration data may be generalized in terms of per cent of air-gap reading vs. wall density, calibrations are independent of source activity (within limits) and the same calibration curve, Figure 7b, may be used while the source intensity is decreasing. A variable resistor in the recorder circuit is used to change the number of counts represented by each chart scale

division. Each day, before profiles are measured, a standard absorber is placed over the window of the GM tube. This absorber is known to have produced a chart reading of exactly 100 (scale factor = 64) at the time of calibration. The potentiometer is then adjusted to again give a 100 chart reading and the probe is ready for use. Every month, when the absorber over the Ru^{106} - Rh^{106} source is replaced, the variable resistor is set back to its original position.

USE OF THE PROBE

Using the mass probe, a series of mass readings on a tubular filter bag can be obtained with the present arrangement at the rate of 45 seconds per point. The sequence of events during a measurement cycle is 30 seconds for counting, 2 seconds for recording the count, and 13 seconds for repositioning the probe to the next sequential location. These timing intervals may, of course, be varied to meet specific test requirements. The results of a series of mass readings is a recorder strip chart containing a series of equally spaced lines, the height of each line being a measure of the wall density at a particular location on the bag.

Based upon a previously determined calibration, tabulations of dust mass measurements, in order along the length of a bag, are obtained by using a Benson-Lehner Semi-Automatic Chart Reader; these data may be subsequently shown graphically if desired.

ACCURACY OF THE PROBE

As indicated earlier, the accuracy with which a mass measurement may theoretically be made may be determined statistically from ideal calibration curves as are given in Figure 1. It will be remembered that accuracy theoretically increases with wall density. The same calculation techniques, when applied to the experimentally determined calibration curves yield the relationships shown in Figure 8 between expected accuracy (i.e., counter reliability) and wall density. For Pb^{210} - Bi^{210} reliability does, in fact, follow the expected trend. For the Ru^{106} - Rh^{106} source, however, it is seen that accuracy is best at about 3000 grains/ft² and that accuracy gradually diminishes for wall densities above this value.

Certain systematic and personal errors are, of course, involved in the use of the probe, but it appears that these are less than the counting errors to be expected. For instance, chart reading error with the automatic chart reader should certainly be less than one-half per cent of the full-scale deflection, and recorder reproducibility is of the same order. Counting errors caused by

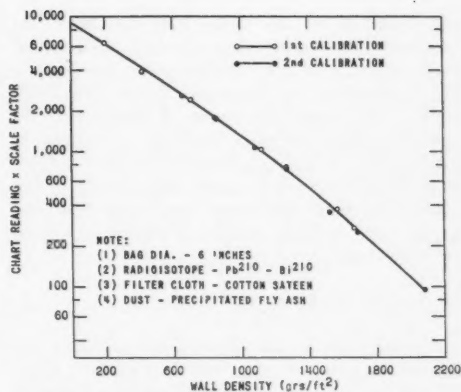


FIGURE 7a. Calibration curve for Pb^{210} - Bi^{210} mass probe.

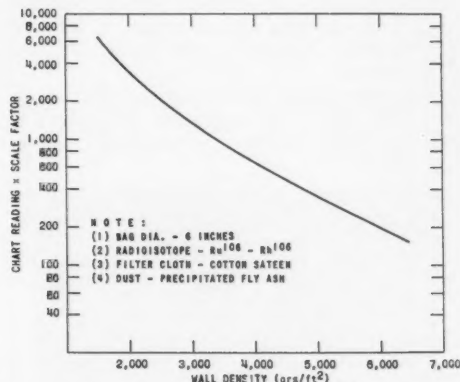


FIGURE 7b. Calibration curve for Ru^{106} - Rh^{106} mass probe.

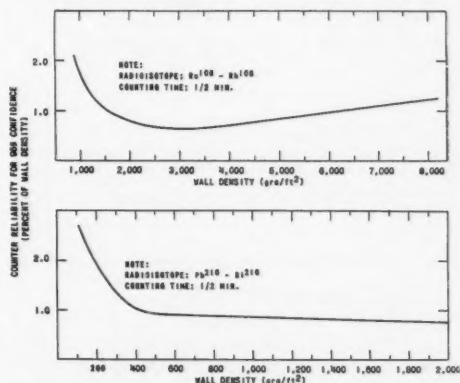


FIGURE 8. Relation between counter reliability and wall density for Pb^{210} - Bi^{210} and Ru^{106} - Rh^{106} mass probes.

misalignment of the probe with the filter bag diameter are also less than one-half per cent for displacements of the probe of up to $\frac{3}{4}$ -inch from the true bag diameter. It has also been shown that negligible error is introduced by "end effect", even when readings are taken as close as $\frac{1}{4}$ - to $\frac{1}{2}$ -inch to either end of a filter bag. The largest error arises undoubtedly in the calibration techniques used, but even here, the actual filter loadings should be known to within one per cent.

The Filter Velocity Probe

A knowledge of the actual filter velocities for the identical locations at which dust cake mass is known is also important. These two types of data, when evaluated in conjunction with pressure drop information, can indicate variations in cake porosity and thereby provide evidence of different packing characteristics or different particle-size distributions over the extent of a filter surface.

An instrument for measuring local filter velocities must have two important properties: it must not affect the filter velocity while a meas-

urement is being made, and it must be able to accurately measure very low velocities on the order of 1 to 10 ft/min. Considering the first of these properties, one may conclude that an extremely low pressure drop through the sensing element is required in order that the gas passing outward through the filter figuratively "does not know" that it is being metered, rather than passing directly to the outside.

Several types of sensing elements were considered, but the thermal anemometer appeared to be ideally suited for such service. Pressure drop through these devices can be made essentially zero, and accurate readings of air velocities as low as 5 ft/min may be obtained. In addition, thermal anemometers are rapid reading, quite convenient for use even in the field, relatively cheap, and their signal may be recorded.

In spite of the ability of the thermal anemometer to sense velocities on the order of 5 ft/min, this is still an order of magnitude greater than the lowest filter velocities which are encountered. Therefore, some type of probe head is required which will collect air from a given filter area and accelerate it to about ten times its original velocity for passage through the anemometer. A wide variety of probe heads were investigated ranging from very soft foam rubber cones, to thin-walled brass ones, to spring-mounted and foam rubber padded designs. The probe head to be used should: (1) not disturb the dust cake within the filter bag (i.e., not require the application of an appreciable force between probe and filter bag), (2) give reproducible readings even when operated by different observers, and (3) give satisfactory readings with both high and low pressure drops across the filter (i.e., for both clean bags and bags containing heavy dust cakes). In addition, it would be very convenient if the probe could be hand-held while readings are being taken.

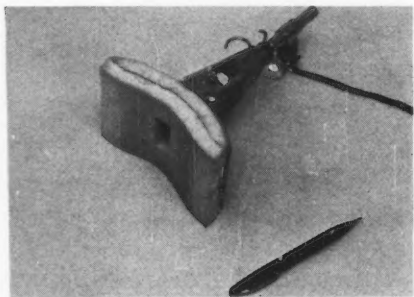


FIGURE 9. Filter velocity probe.

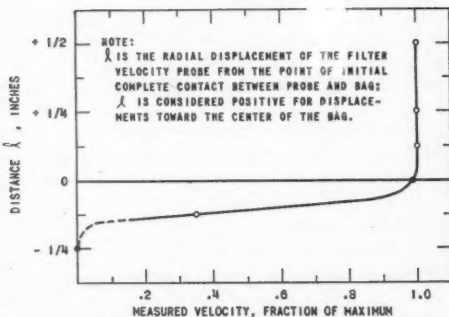


FIGURE 10. Effect of probe position on measured filter velocity.

DESIGN OF PROBE

The probe-head design finally selected is shown in Figure 9. It consists of a rectangular cross-sectioned truncated pyramid to which a Hastings-Raydist thermal anemometer gauge tube is fastened. On the inlet end of the cone are two screen "wings" faced with a double layer of $\frac{1}{2}$ -inch foam rubber. In the center of the foam rubber pad is a rectangular hole through which the air "filtrate" passes into the pyramidal section and thence to the anemometer. This particular head design has been found to give reproducible readings and to require a minimum of pressure against the filter bag. As seen in Figure 10, the velocity reading obtained

increases very rapidly as the probe approaches within 1/4-inch of the bag. As the probe just touches the bag surface, the indicated reading is within one or two per cent of the maximum value which can be obtained.

Originally the velocity reading was made on an indicating millivoltmeter supplied with the gauge tube. This, however, required the presence of two operators. To allow one-man operation, the probe output was fed through a selector switch to the millivolt recorder⁵ used for taking mass probe readings. Once this was done, one technician could make complete filter velocity traverses, the result being recorded as a series of peaks on the recorder strip chart. It is estimated that the cost of materials for the recording filter velocity probe, exclusive of recorder itself, is well below \$100.

CALIBRATION OF THE PROBE

Data for a basic calibration curve for the filter velocity probe, millivolts vs ft^3/min , were obtained through use of a wet test meter in series with the thermal anemometer gauge tube. The probe calibration curve, Figure 11, is then obtained by dividing the various volumetric flow rates by the effective open face area of the probe head (1.83 in.^2). An accurate volumetric flow rate to a given filter bag can be measured in the laboratory, this flow rate divided by the total surface area of the bag being the average filter velocity (filter ratio). The effective probe area is then determined by dividing the mean volumetric flow rate through the probe by this average filter velocity. The mean volumetric flow rate used above is the average of flow rates through the probe measured at specific points on the filter, the average being representative of the entire surface of the test filter bag.

USE OF THE PROBE

In practice, the chart reading for zero flow through the probe is adjusted to a prescribed value by varying the alternating current to the anemometer with a precision potentiometer. After the correct zero-flow reading has been established, the probe, with discharge end still closed, is placed gently against the bag surface at the first point of the desired profile. The probe is then opened for about two seconds, producing a square peak on the recorder chart. With discharge end again closed, the probe is moved to the second position and another two-second reading taken. Eleven-point profiles along the length of a 6-foot filter bag have been produced in this way in less than a minute. The data on the strip chart are converted to tabulated filter velocities and these values are subsequently

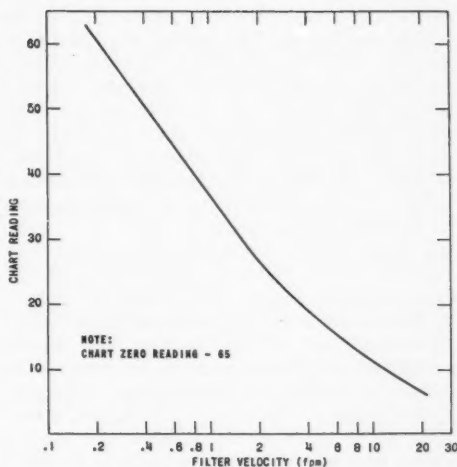


FIGURE 11. Calibration curve for filter velocity probe.

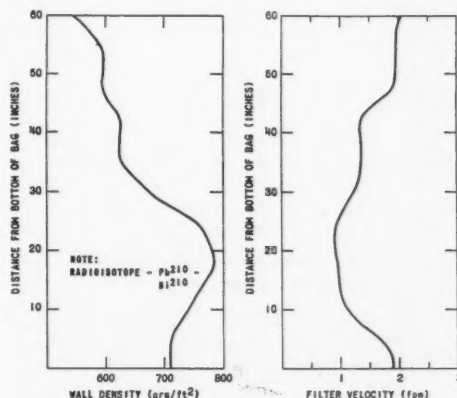


FIGURE 12. Corresponding mass and filter velocity profiles obtained with instruments developed.

plotted as shown in Figure 12. The expected inverse relationship between mass and filter velocity is demonstrated quite clearly by the corresponding mass and filter velocity profiles shown in this figure.

ACCURACY OF THE PROBE

Because the pressure drop through the probe is on the order of one per cent of the pressure drop across the filter, and because the filter area effectively blocked by the foam rubber face on the probe is less than one or two per cent of the total filter area (these factors tend to compensate for one another), the filter velocity

through the local area being metered should be within at least one per cent or so of the filter velocity when the probe is not present. Hence, the potential accuracy of the filter velocity probe is quite high. Variations in other factors, however, combine to increase the uncertainty of measurements with this probe. The emf generated by the sensing thermocouple, the response of the millivolt recorder, and the technique used by the operator in placing the probe against the bag all contribute to measurement error. The operator error is by far the most important. For filter velocities greater than about one ft/min, operators can reproduce measurements within about 5 per cent. Below 1 to 1.5 ft/min the absolute reading error appears to be roughly constant, thus making the percentage error increase as the velocity decreases. At 0.5 ft/min, errors of as much as 10 per cent are to be expected. These personal errors in individual readings are apparently random in nature, however, since material balances on air flow into and out of a test filter bag (air flow out based on a

relatively large number of filter velocity readings) check within two to three per cent.

Acknowledgments

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Joseph M. DallaValle

On June 1, 1958, Dr. Joseph M. DallaValle, 52, died at Atlanta, Georgia. He was widely known among industrial hygienists for his research and publications on ventilation and particulate materials. He received his bachelor's degree at Harvard in 1927, his master's in 1928, and his doctorate in 1930. At the time of his death, he was regent professor of chemical engineering at Georgia Tech.

Walter C. Wagner

On April 22, 1958, Walter C. Wagner died at Ardmore, Pennsylvania. He was a consultant on air pollution problems to the Greater Philadelphia Chamber of Commerce. He received the bachelor's degree in engineering at the University of Washington in 1907 and the master's in mechanical engineering at Cornell in 1911.

Toxicity, Excretion and Tissue Distribution of Ionium (Th^{230}) in Rats*

IRENE U. BOONE, BETTY S. ROGERS, D. C. WHITE†
and PAYNE S. HARRIS

*Los Alamos Scientific Laboratory, University of California,
Los Alamos, New Mexico*

The radioactive isotope ionium (Th^{230}) is of interest because it serves as a tracer for natural thorium, which is processed industrially in rather large quantities, and because it is encountered in uranium ore processing. There is little information available concerning the physiology and toxicology of ionium and in particular no data for establishing adequate health standards.

Experiments on excretion, tissue distribution, and acute toxicity following intravenous administration of ionium in rats were undertaken. In addition, separate groups of animals were injected for histopathological and radioautographic studies. Because of their chemical similarity, ionium and plutonium would be expected to have similar physiological and toxicological properties when administered to animals on an equivalent microcurie basis. Therefore, the results of this study were compared with those obtained from previous studies done with plutonium at this Laboratory.

Experimental Methods and Procedures

Male Sprague-Dawley rats weighing between 200 and 300 gm were used. All ionium solutions were administered intravenously via the jugular sinus. Doses were administered on the basis of $\mu\text{c}/\text{kg}$ of body weight, and the ionium concentrations were adjusted so that the volume of injected solution did not exceed 0.8 ml.

PREPARATION OF SOLUTIONS

The original solution of ionium was obtained from the Uranium Division of Mallinckrodt Chemical Works. The ionium solution was obtained by a recent separation from Uranium-238 feed materials. Assay of the solution showed that it contained 1 gm (19.3 me) Io/liter in 60 per cent nitric acid. A sample of the solution was converted to the thorium oxide and ana-

lyzed in a low sensitivity mass spectrometer. Atomic abundance ratio of the $\text{Th}^{232}/\text{Th}^{230}$ (Io) was 7.94 ± 0.16 . No other peaks were found.

The injection solution was prepared by evaporating an aliquot of the original solution to dryness and reoxidizing three times with 6 N HNO_3 . A 10 per cent solution of sodium citrate was used to complex the ionium precipitate into solution. Solutions varying in concentration from 16.4 to 38.6 μc Io/ml were prepared in this manner and adjusted to pH 6 to 7. An assay of activity in each solution was determined before injection.

LETHALITY, EXCRETION, AND TISSUE DISTRIBUTION

From three to twelve animals per dose were injected intravenously with doses of ionium ranging from 19.3 μc to 130 $\mu\text{c}/\text{kg}$ of body weight. Following injection, the animals were housed individually in wire-bottom metabolism cages equipped with a glass funnel constructed to facilitate the simultaneous but separate collection of urine and feces. The exact number of animals used in each determination is indicated in the tables and graphs presented in the Results.

Twenty-four hour urine and fecal collections were obtained on three to six animals per dose group for the first six to eight days, and single 24-hour collections were obtained each succeeding week on survivors.

In addition to the excretion collections, the animals were weighed once or twice a week for at least 36 days or until the time of death. At death of the animal the spleen, liver, and kidneys were removed and ashed in a muffle furnace at 700°C . The carcass was ashed and the bones separated from the ash for assay. The bone, tissue, and fecal ash were dissolved and diluted with 6 N HNO_3 . Urine samples were not diluted. Sufficiently small aliquots were plated directly on stainless steel plates (15.8 cm^2 , surface area) such that self-absorption

*Work done under the auspices of the U. S. Atomic Energy Commission.

†Major, U. S. Army Element, AFSWP, Sandia Base, stationed at Los Alamos, New Mexico.

corrections were unnecessary. All counting was done in a methane flow proportional counter.

After the above preliminary lethality results were obtained, a more precise LD_{50} determination was done with six to ten rats per dose injected at dose levels of 28.6, 33.6, 38.8, 41.9, and 45.0 μc I^{131}O /kg of body weight.

HISTOPATHOLOGY AND RADIOAUTOGRAPHS

Three animals receiving 130 μc I^{131}O /kg of body weight were sacrificed on the eighth day following intravenous injection, while three animals injected with a dose of 19.3 μc I^{131}O /kg were sacrificed five weeks after injection. Complete autopsies were performed on each animal and tissues were taken for pathological examination. Femur, tibia, vertebra, liver, spleen, and kidney were taken for survey-type radioautographs. The bone sections were cut without decalcification and placed in contact with dental x-ray film.

TABLE I
Toxicity of I^{131}O Citrate Administered
Intravenously to Rats

$\mu\text{c}/\text{I}^{131}\text{O}/\text{kg}$ Body Weight	Number Animals	Survival Time (days)	
		Median Survival	Range
130.00	6	8.0	7-10
108.00	6	9.0	6-32
86.90	3	17.0	10-21
38.60	12	30.0	10-50
29.00	12	45.0	34-129
19.30	11	120.0	70->212

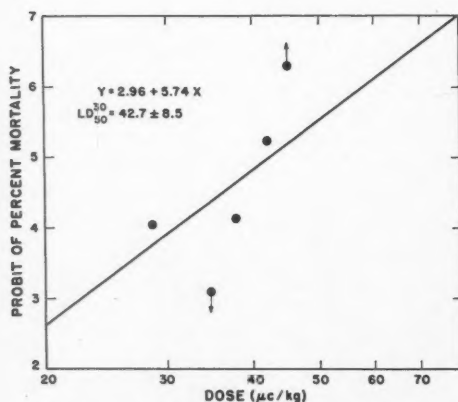


FIGURE 1. Probit analysis of 30-day mortality for rats following intravenous administration of I^{131}O citrate.

In addition, tissue sections were taken for histopathological examination from a few of the animals included in the lethality studies.

CHEMICAL TOXICITY OF Th^{232}

To eliminate the possibility of inert Th^{232} , present as a carrier in the ionium solution, contributing to the toxicity of the ionium, rats were injected intravenously with a citrate solution of thorium nitrate. Six rats per dose were injected with 40.5, 50.4, and 60.3 mg Th^{232} /kg of body weight. This was equivalent to the total thorium administered at the three highest ionium dose levels.

Results

LETHALITY

Table I summarizes the data obtained from the preliminary lethality studies. Both the median survival time and the range of survival in days are given for each dose. The median survival time was determined by plotting the per cent of survivors versus time on standard probit paper and then using the best fit line to obtain the 50 per cent survival point.

Figure 1 shows the probit regression line for ionium obtained by plotting the probit of the 30-day mortality against dose. The equation for the regression line was

$$Y = 2.96 + 5.74X$$

where Y = probit of per cent mortality, and X = log dose. These data show that the 30-day median lethal dose, under the conditions of these experiments, was 42.7 ± 8.2 $\mu\text{c}/\text{kg}$ of body weight.

All animals invariably lost weight from the second to fourth day after injection. Although the extent of weight loss was generally correlated with dose, there was considerable variation among the animals in each group. Death invariably followed in any animal which lost 40 per cent of its original weight by the fourth day following injection. Animals surviving for more than 30 days had an initial weight loss of 15 to 30 per cent, which was regained by the twenty-fourth day.

EXCRETION AND TISSUE DEPOSITION OF IONIUM

Table II shows the daily urinary and fecal excretion of ionium when administered intravenously to the rat as the I^{131}O citrate complex at dose levels two to three times the LD_{50} dose. The values in the table are averages of the determinations performed on the number of animals indicated. During the first day the urinary

TABLE II
Urinary and Fecal Excretion of I^{131} Citrate Following Intravenous Administration in Rats
(Percentage of Injected Dose Excreted per Day)

Day after Injection	86.9 $\mu\text{C}/\text{kg}$				108 $\mu\text{C}/\text{kg}$				130 $\mu\text{C}/\text{kg}$			
	Number Animals	Urine	Feces	F/U	Number Animals	Urine	Feces	F/U	Number Animals	Urine	Feces	F/U
1	3	28.70	0.547	—	6	18.80	0.426	—	9	18.80	—	—
2	3	0.126	—	—	6	0.084	—	—	9	0.288	—	—
3	3	0.089	0.836	9.4	6	0.035	0.841	24	9	0.061	0.369	6.0
4	3	0.031	0.214	6.9	6	0.026	0.286	11	9	0.046	—	—
5	3	0.061	0.240	15.0	6	0.038	0.367	9.6	9	0.058	0.152	2.6
7	3	—	—	—	—	—	—	—	5	0.020	—	—
8	—	—	—	—	—	—	—	—	4	0.014	0.011	0.8
9	—	—	—	—	—	—	—	—	2	0.002	—	—
10	3	0.015	0.094	6.3	3	0.013	0.085	6.5	—	—	—	—
18	2	0.009	0.017	1.9	1	0.007	0.027	3.9	—	—	—	—
31	—	—	—	—	1	0.005	0.006	1.2	—	—	—	—

excretion was 18 to 27 per cent of the injected dose with the majority of this excretion occurring in the first eight hours after injection. Fecal excretion the first day was 0.3 to 0.6 per cent of the injected dose. The urinary excretion rate

decreased rapidly and by the fourth to fifth day dropped to less than 0.04 per cent, while the fecal-urinary ratio ranged from 5 to 15, varying slightly with the dose level. For animals surviving the tenth day after injection, the urinary excretion dropped below 0.01 per cent of the injected dose, and the fecal-urinary ratio approached one.

Urinary and fecal excretion data at dose levels of from 19.3 to 38.6 $\mu\text{C}/\text{kg}$ of body weight were plotted in Figures 2 and 3 as per cent of injected dose excreted per day and eye-fitted curves drawn through the data. Figure 4 is a plot of the fecal-urinary ratio at these dose levels. Each point represents the average of the determination from six animals for each dose except the 36- and 43-day points of the 38.6 μC dose level. These two points are the average of determinations on four and three animals, respectively. At these lower dose levels from 6 to 10 per cent of the injected dose was excreted in the urine in the first 24 hours. The 24-hour urinary excretion rate rapidly dropped to ~0.04 per cent of the injected dose on the third day,

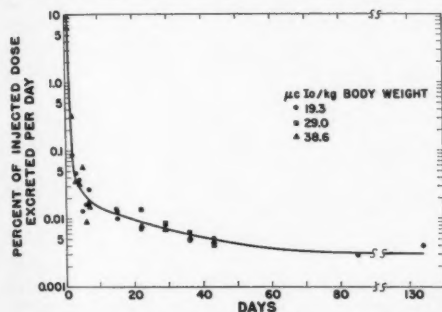


FIGURE 2. Urinary excretion of ionium following the intravenous administration of I^{131} citrate at the doses indicated.

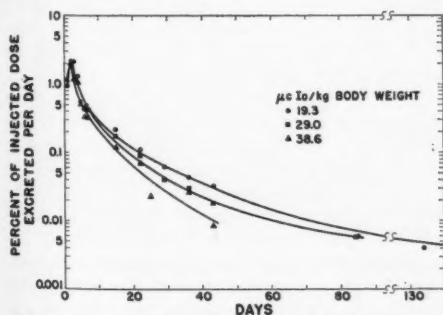


FIGURE 3. Fecal excretion of ionium following the intravenous administration of I^{131} citrate at the doses indicated.

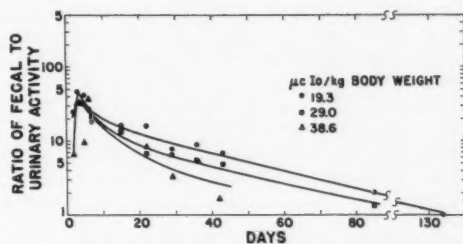


FIGURE 4. Fecal-urinary excretion ratio of ionium following the intravenous administration of I^{131} citrate at the doses indicated.

TABLE III
Tissue Distribution of Ionium Following Intravenous Administration to the Rat
(Percentage of Injected Dose*)

Dose† μc/kg Body Wt.	Number Animals	Skeleton	Soft Tissue				Total Soft Tissue	Urine	Feces	Total
			Liver	Spleen	Kidney	Balance				
130	6	37.2	14.3	2.10	4.2	19.1	39.7	19.2	1.56	97.7
108	6	35.0	11.0	0.27	1.8	17.9	31.0	23.8	1.83	91.6
86.9	3	33.8	11.3	0.78	1.4	18.8	32.3	29.3	1.90	97.3
38.6	8	25.6	13.7	1.10	1.2	32.7	48.6	10.0‡	7.40‡	91.6
29.0	5	17.7	13.1	1.15	1.2	37.0	52.5	—	—	—
19.3	2	19.7	13.9	—	—	38.5	52.4	6.5‡	11.4‡	93.5

* An average of tissue analyses performed on animals at the time of death. Median survival time indicated in Table I for each dose level.

† 1 mg Io = 19.3 μc.

‡ After the sixth day, estimated on the basis of excretion rate and survival time.

while the fecal-urinary ratio ranged from 30 to 45. At a dose level of 38.6 μc/kg of body weight, the integrated urinary excretion was ~10 per cent at 30 days. At this time the daily urinary excretion rate was 0.007 per cent of the injected dose. In this same period the total fecal excretion was ~5 per cent. Seven days postinjection, the fecal-urinary ratio was ~20. In surviving animals this ratio was 3 to 5 at 30 days, and approached one at 45 days.

The results of tissue distribution studies for ionium are presented in Table III. Since the tissue distribution pattern did not vary significantly over the survival range at each dose level, the values are reported as an average of the number of animals indicated. The level of tissue deposition varied only slightly with the size of the dose administered. In general, an average of 70 to 80 per cent of the injected dose was retained at the time of death. At the high dose levels (two to three times the LD_{50}^{30}), the retained portion was equally divided between the bone and the soft tissue. Of the portion retained in the soft tissue, about one-third was found in the liver. At dose levels in the LD_{50}^{30} range (19 to 40 μc/kg), the total amount of ionium retained at the time of death was similar to the high dose levels but the skeleton and soft tissue ratios differed. Approximately one-third of the retained ionium (or 17 to 26 per cent of the initial dose) was in the skeleton and two-thirds (50 per cent of the total dose) in the soft tissue. Of the amount of ionium found in the soft tissue, approximately 25 to 30 per cent was in the liver.

HISTOPATHOLOGY AND RADIOAUTOGRAPHY

The histopathological findings consisted principally of changes involving a loss of functional cells and atrophy. In those animals upon which

autopsies were performed and tissues removed for histologic preparation, only certain organs and organ systems revealed significant pathologic changes. The most prominent lesions were found in the kidney, bone marrow, and lymphoid system. The degree of damage appeared to be related to the amount of ionium administered. In those animals receiving 130 μc/kg of body weight, the renal damage was severe with the pathological changes restricted to the tubules and, more specifically, to those portions of the convoluted tubules in the region of the cortico-medullary junction. The glomeruli appeared to be essentially normal, and the proximal convoluted tubules of the peripheral cortical zone exhibited only scattered segments with epithelial degeneration. The distal tubules, on the other hand, revealed profound damage with almost total destruction of the lining epithelium. The normally distinct cell borders were obscured. There was a loss of cellular cohesion with a "dropping off" of the cells into the tubular lumen. The cytoplasm showed an irregular granularity and frequent vacuolization. The nuclei, in general, were pyknotic, fragmented, or entirely lost. The tubular lumens were occluded by cellular debris.

Although these degenerative changes were widespread and very severe, significant epithelial regeneration had occurred by the eighth day postinjection. In the areas of regeneration the new, proliferating epithelial cells were irregularly spaced along the basement membrane. Some were closely packed even to the extent of becoming heaped-up in a pseudo-papillary fashion. In other areas the regenerating cells were widely spaced and assumed an elongated, flattened appearance. The collecting tubules were only secondarily involved with occlusion of many of the lumens by casts. The lining epithelium of the

renal pelvis was unaltered, and the interstitial tissues showed no inflammatory infiltrate.

The damage incurred by the bone marrow was of equal severity. In those animals receiving 130 $\mu\text{C/kg}$ of body weight, the marrow was devoid of the usual cellular components. The bone marrow was largely replaced by fat cells, dilated and congested capillaries, and scattered cells of the reticulum type. In those animals receiving 19.3 $\mu\text{C/kg}$ of ionium and sacrificed at about five weeks postinjection, a marked marrow hypoplasia was present. At this stage, however, many scattered islands of regenerating or persisting marrow precursors were in evidence and young megakaryocytes were relatively numerous. In animals which survived a period of several months, the marrow reverted to an essentially normal picture.

The lymphoid system, specifically the spleen, presented a consistent depletion of lymphocytes. In the higher dose range, this resulted in almost complete loss of the lymphocytes. The over-all splenic architecture remained intact; however, the Malpighian bodies were greatly diminished in size and consisted of a well defined center containing a loose admixture of reticulum cells, lymphocytic cell debris, and macrophages heavily laden with degenerating nuclear fragments. In some instances, there was a thin surrounding cuff of lymphocytes. The sinusoids of the red pulp areas were, for the most part, collapsed and essentially devoid of erythrocytes. Pigment deposition was a prominent feature in all sections, and the majority of this pigment was identified as hemosiderin by special staining procedures. In those animals receiving 19.3 $\mu\text{C/kg}$

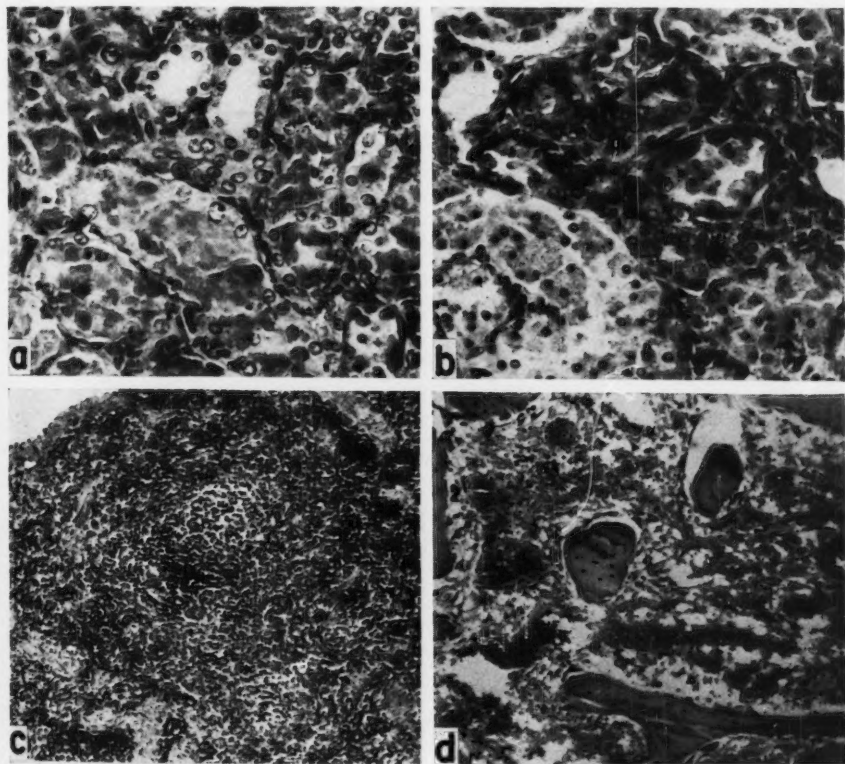


FIGURE 5. Histopathological changes following the intravenous administration of ionium in the rat (hematoxylin and eosin).

(a) and (b) degenerative and regenerative changes in the renal convoluted tubules ($\times 258$).

(c) depletion of lymphocytes of the splenic lymphoid follicle ($\times 103$).

(d) marked hypoplasia of the bone marrow ($\times 103$).

of body weight of ionium and surviving for longer periods, the histological picture was similar but there was a progressive increase in the number of lymphocytes in the follicular areas. Representative photomicrographs of the histo-

pathological changes described are shown in Figure 5.

The survey-type radioautographs showing the mode of deposition of ionium in rat tissues are shown in Figures 6 and 7. In the spleen, the

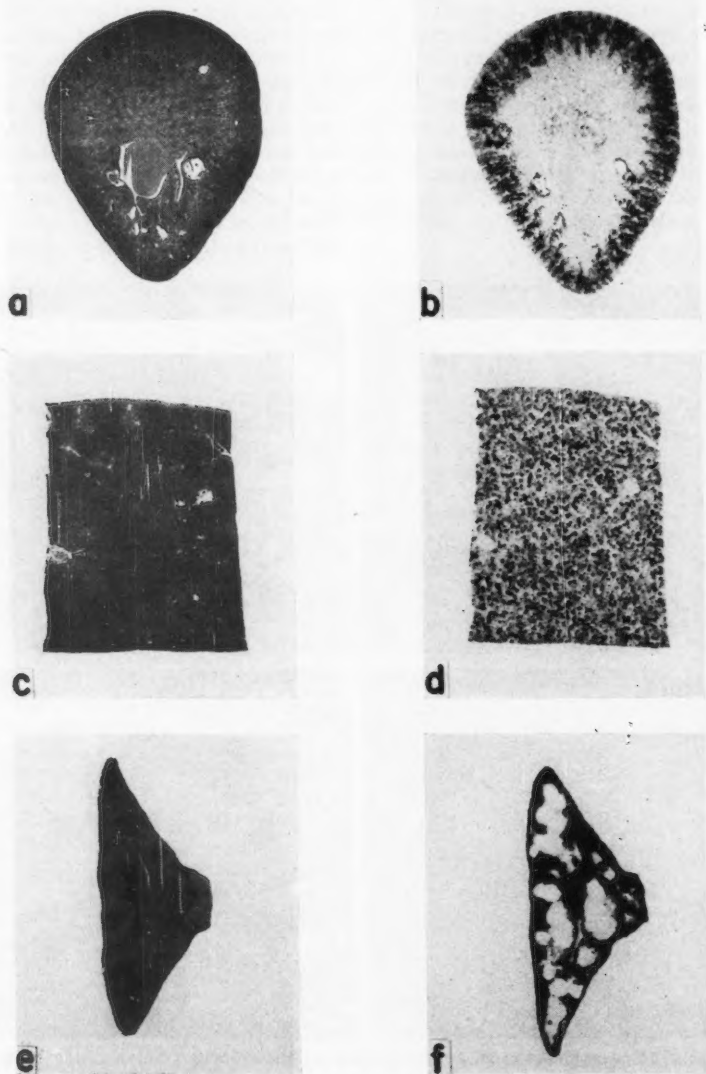


FIGURE 6. Survey-type radioautographs showing mode of deposition of ionium in soft tissue of the rat.

(b), (d) and (f) are the radioautographs of the kidney, liver, and spleen, respectively. (a), (c) and (e) are the corresponding photomicrographs.

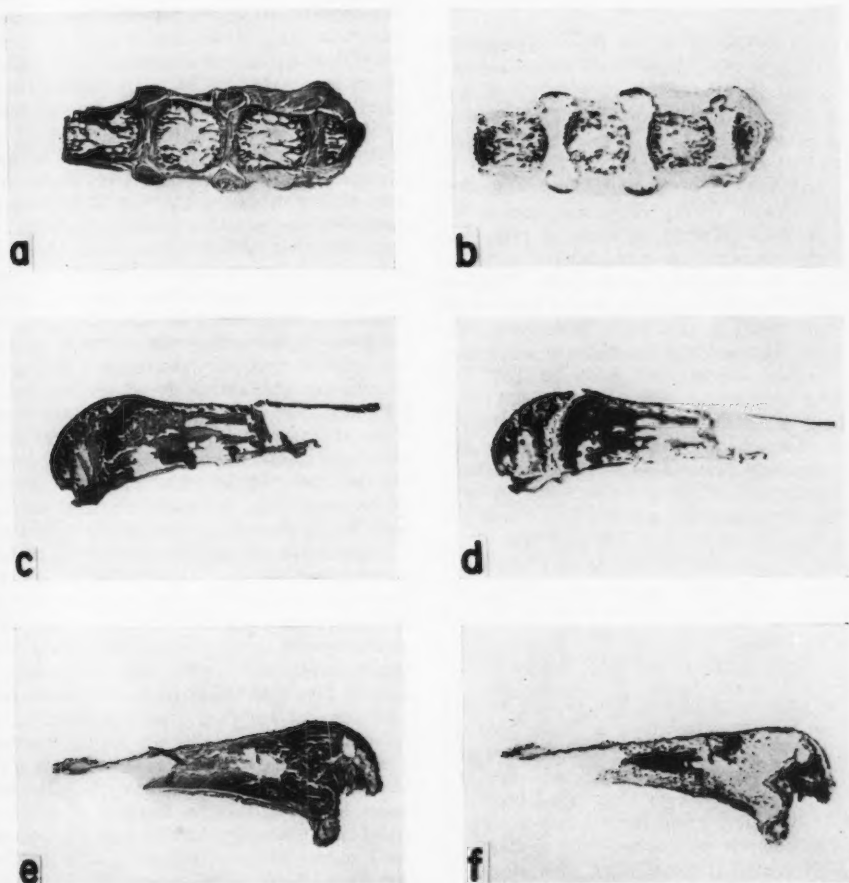


FIGURE 7. Survey-type radioautographs showing mode of deposition of ionium in the bone of the rat.

(b), (d) and (f) are the radioautographs of the vertebra, femur, and tibia, respectively.

(a), (c) and (e) are the corresponding photomicrographs. Note in particular ionium in the bone marrow of the tibia and femur.

radioactivity was densely concentrated in the red pulp, while the white pulp was sharply demarcated by the absence of ionium. Small discrete areas of radioactivity were found in the liver, appearing to concentrate in the reticulo-endothelial cells. Ionium in the kidney was almost exclusively concentrated in the cortex and appeared to be associated primarily with the tubules. Sites of incorporation of ionium in the long bones were primarily the zone of provisional calcification in the epiphyseal cartilage, the endosteal and periosteal lines, the bone marrow, and the trabeculae of the metaphysis. There

was evidence of some radioactivity in the epiphysis but none in the epiphyseal line or cartilage proper. The heaviest concentration was in the zone of new bone formation.

CHEMICAL TOXICITY OF Th^{232}

None of the rats receiving Th^{232} in the dose range of from 40 to 60 mg/kg of body weight died during the course of the experiment. These animals were observed for at least 30 days after injection. No significant pathological changes were found on preliminary examination of tissues from animals which received inert thorium.

Discussion

Under the conditions of these experiments, the 30-day median lethal dose of ionium was 42.7 $\mu\text{C}/\text{kg}$ of body weight. The LD_{50} dose of plutonium, reported from this laboratory by Langham et al.^{1,2} was 71 $\mu\text{C}/\text{kg}$. The alpha particles emitted have energies of 4.7 Mev for ionium and 5.16 Mev for plutonium. Therefore, on the basis of energy deposition, ionium appears to be ~ 1.5 times as toxic as plutonium when the elements are administered intravenously and the end point is acute death. The presence of Th^{232} in the ionium injection solution did not contribute to the acute toxicity as was shown by the results of the study in which only inert thorium was injected. Also, the Th^{232} content of the ionium solution was below that which has been reported to cause chemical toxicity.³⁻⁷

The excretion of ionium is controlled by several competing rate processes. Thus the excretion function (time change in per cent per day) can be represented by a series of exponentials over a long period of time. The half-time of the function as indicated by the slope of each exponential is an index of the controlling rate parameter. Also, the excretion level at the time of introduction of a new exponential fit is an index of the excretion that has occurred previous to that time.

From these experiments, the ionium urinary excretion function consists of at least three exponentials (or a single exponential and a single hyperbolic function). At early times, the urinary excretion rate is very high with a half-time of about 0.15 day. From three to seven days a second component with a half-time of about 15 days is evident. At times later than 40 to 50 days, the urinary excretion rate becomes extremely small, and the half-time approaches years.

It is possible to compare the excretion in rats of Io^{+4} and Pu^{+4} by reference to earlier work.²

TABLE IV
Urinary Excretion of Io^{+4} and Pu^{+4}
(Excretion rate expressed as percentage of dose injected per day)

	0-3 Days		7-50 Days		Total Urinary Excretion	
	Excretion Rate on Day 1	Half-Time of Excretion Rate (days)	Excretion Rate on Day 7	Half-Time of Excretion Rate (days)	0-7 Days	7-50 Days
Ionium	8.00	0.15	0.02	15	8.5	0.3
Plutonium	0.55	0.70	0.075	15	1.2	1.0

For the first 40 days after injection, plutonium excretion can also be represented by two exponentials. Again one component is fast, and the other is relatively slow. The arithmetic constants for urinary excretion evaluated for the two isotopes are given in Table IV.

By comparison of the arithmetic constants, several deductions can be made. The excretion rate of ionium during the first 24 hours is high compared to plutonium. This indicates that clearance from the blood to tissue reservoirs is much slower in the case of ionium. However, for the period of one to three days, the ionium is cleared to tissue reservoirs and, therefore, is not available to the kidney for excretion at a rate any higher than for plutonium. This is evidenced by the extremely short half-time of 0.15 day. For the second period from 7 to 50 days, the excretion function half-times for ionium and plutonium are the same. Therefore, the resultant of all rate processes involved, which include the various blood, soft tissue and bone transfers, is the same for the two isotopes.

The initial excretion level at day 7 is inversely proportional to the initial level for the first 24-hour period and directly proportional to the excretion decay constant for the rapid portion of the excretion function. Although the excretion rate for plutonium is about four times as high as that for ionium from 7 to 50 days, the total amount excreted does not make up the difference introduced by the initial low rates.

The fecal excretion of ionium is also represented by a complex series of exponential functions. The initial rise in fraction of total dose excreted is evidently the result of the establishment of equilibrium between the blood, liver, and fecal stream. After a few days the change in excretion rate may be represented by a single exponential function with a decay half-time of about eight days until about 50 days. At later times, the change in excretion rate becomes very small as was found in the case of urinary excretion. The level of excretion at these late times corresponds rather closely to that for the urinary pathway. The results also indicate that the excretion rate is directly proportional to the initial dose. This is shown by the fact that although the excretion functions are parallel with equal decay half-times, the percentage of initial dose excreted per day varies with initial dose at any particular day.

The comparison between ionium and plutonium in terms of fecal excretion after intravenous injection can be made at times after equilibrium has been established. The decay of the excretion rate is the same for both isotopes with a half-time of about eight days. Here it

appears that the initial excretion rate for plutonium is about four times that for ionium, and thus the total fecal excretion (at least to 50 days postinjection) is four to five times greater.

The changing ratio of fecal excretion rate to urinary excretion rate after intravenous injection of ionium is apparent from the two different half-times. A few days after injection, these are eight days for the change in fecal excretion rate, and 15 days for the change in urinary excretion rate. This indicates that at least up to 50 days after injection the fecal-urinary ratio is decreasing. A changing ratio would be particularly important in the case of inadvertent human exposure in which the mode of exposure would ordinarily be by inhalation. Interpretation of excretion data would be difficult because of the lung reservoir, unless the fecal-urinary ratio versus time were known.

Comparison of I^{131} and Pu^{239} fecal-urinary ratios can also be made over the 5- to 50-day time postexposure. In this case the rate of change of the ratio is the same for both isotopes, and the decay constant is approximately 0.04 per day. The initial levels for the ratio do differ, however, and at five days are about 20 and 25 for ionium and plutonium, respectively. These levels differ considerably. However, the absolute urinary excretion rates and the variations in fecal-urinary ratio tend to cancel each other for purposes of comparison of integrated excretion of both isotopes.

The tissue concentrations of I^{131} citrate, Pu^{239} citrate, and $\text{Pu}(\text{NO}_3)_3$ are compared in Table V. It should be pointed out that the plutonium data were obtained from a previous study conducted at this laboratory by other investigators using a different series of animals. Since the two experiments were not performed simultaneously, the results may not be strictly comparable. The gross tissue distribution of ionium activity varied considerably from that of plutonium when both isotopes were administered in the +4 valence state as the citrate complex. In comparing tissue concentrations following intravenous administration of doses in the LD_{50} range, plutonium levels in the bone were twice as high as ionium. In the liver, the reverse situation was true since ionium concentrations in this organ were three times that of plutonium.

The tissue distribution of ionium more closely resembled that of Pu^{239} nitrate with each isotope equally distributed between the skeleton and soft tissue. However, if the concentrations found in individual soft tissues are compared, the liver concentration of plutonium is twice that for ionium, whereas the balance of soft

TABLE V
Comparison of Tissue Distribution of Ionium and Plutonium Following Intravenous Administration to the Rat (Percentage of Injected Dose*)

Tissue or Excrement	I^{131} Citrate†	Pu^{239} Citrate‡	$\text{Pu}(\text{NO}_3)_3$ ‡
Kidney	1.2	0.79	0.74
Liver	13.7	4.16	26.14
Skeleton	25.6	60.30	30.88
Spleen	1.1	0.60	1.40
Balance	32.7	10.15	7.28
Feces	7.4	20.83	26.03
Urine	10.0	2.15	1.69
Total	91.6	99.00	94.20

* Amount injected of each element was approximately the LD_{50} dose per kg body weight.

† An average of tissue analyses performed on animals at the time of death. Median survival time ~30 days.

‡ Analysis of tissues from animals sacrificed 16 days after injection. Tissue concentrations at 16 and 48 days after injection did not differ significantly.

tissues accounts for four times as much ionium as plutonium.

Some of the differences in tissue localization between these two isotopes may be explained by the predilection of ionium for the cells of the reticulo-endothelial system, presumably due to the formation of insoluble colloids in the blood following the intravenous administration of ionium. Radioautographs of the soft tissue and bone tend to substantiate this explanation. Although the pattern of deposition in the liver and spleen were similar for both ionium and plutonium,⁸ variations of distribution were seen in the radioautographs of the kidney and bone.

Kidney radioautographs have shown plutonium to be concentrated primarily in the papillary region,⁸ while ionium was confined to the cortical region. The renal damage seen on microscopic examination of the tissue sections is a reflection of this distribution of ionium. The cellular regeneration and degeneration were localized in the convoluted tubules, which may indicate that ionium is selectively excreted and absorbed. Early reports^{8, 10} on the cellular damage of the renal tubules following the injection of plutonium have indicated the pathogenesis to be similar to that described for ionium. A correlation between tissue distribution and damage cannot be made since specific locations of pathological findings in the kidney have not been described.

Radioautographs of the bone indicate similar distribution for ionium and plutonium,^{8, 10} except that ionium is also deposited directly into the marrow cavity. The heavy concentration of

ionium in the reticulo-endothelial cells of the bone marrow, as well as its wider distribution throughout the reticulo-endothelial system, may account for the greater acute toxicity of ionium as compared to plutonium.

These findings indicate the acute toxicity dose level of ionium is lower than that for plutonium. This is apparently due to differences in tissue distribution with concentration of this material in the marrow spaces in the bone. Since direct irradiation of the hemopoietic system is involved, the actual dose to sensitive and acutely responding tissue is greater for ionium than for plutonium, even though the concentration in the total skeleton is less.

The results do not, however, indicate that the maximum permissible level for chronic ionium exposure should be less than that for plutonium. First, the mode of entry of the material into the body in case of accident or chronic exposure would probably not be by intravenous injection. Secondly, the material would probably not be in the chemical form used. Finally, chronic exposure is based on low continuous levels, where the actual bone marrow concentrations would be exceedingly small. These factors would probably have some effect on the total dose and dose rate to the hemopoietic system. They could only be accurately evaluated by low-level chronic experiments on suitable experimental animals. Therefore, it can only be recommended that maximum permissible levels for ionium exposure be the same as those for plutonium. This in itself is somewhat conservative, since the greater total excretion of ionium has not been considered.

Summary

The excretion, tissue distribution, and toxicity of ionium (Th^{230}) were studied following its intravenous administration in the rat. In addition, separate groups of animals were injected with ionium for histopathologic and radioautographic tissue studies. The results are summarized as follows:

1. The LD_{50} dose of ionium for the male Sprague-Dawley rat was $42.7 \mu\text{c/kg}$ of body weight.

2. At dose levels in the LD_{50} range, the total urinary excretion of ionium was ~ 10 per cent at 20 to 30 days. At 30 days, the urinary excretion rate was 0.007 per cent of the injected dose per day. In this same period, the total fecal excretion was ~ 5 per cent. Seven days postinjection, the fecal-urinary ratio was ~ 20 . In sur-

viving animals this ratio was three at 30 days, and approached one at 45 days.

3. The level of tissue deposition of ionium varied slightly with the size of the dose administered. An average of 70 to 80 per cent of the injected dose was retained at the time of death at dose levels from 19 to $130 \mu\text{c/kg}$. At dose levels in the LD_{50} range, 25 to 30 per cent of the retained material was found in the bone, and ~ 50 to 60 per cent in the soft tissues. Half the latter was found in the liver.

4. Histopathological findings consisted principally of changes involving loss of functional cells and atrophy. The most prominent lesions were found in the kidneys, bone marrow, and lymphoid system. The degree of damage appeared to be related to the amount of ionium administered.

5. Survey-type radioautographs showed that the distribution of ionium in the liver and spleen was associated with the reticulo-endothelial cells. Ionium concentration in the kidney was almost exclusively in the cortex and appeared to be associated primarily with the tubules. Sites of incorporation of ionium in the long bones were primarily the zone of provisional calcification in the epiphyseal cartilage, the endosteal and periosteal lines, bone marrow, and trabeculae of the metaphysis.

Because of the isotopic similarities between the two metals, these results were compared with those from previous studies done with plutonium in this laboratory. The toxicological and physiological properties of ionium indicated that the maximum permissible dose levels should be at least those of plutonium.

Acknowledgment

The authors are indebted to Mrs. Julie Wellnitz for the radioautographs and photomicrographs.

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NOISE ABATEMENT SYMPOSIUM

THE NINTH ANNUAL NOISE ABATEMENT SYMPOSIUM will be held October 9 and 10, 1958 at the Hotel Sherman in Chicago. Papers and discussions will include topics on the control of industrial noise and the reduction of noise in manufactured consumer products and appliances. The control of noise in jet airliners will be a major item of interest.

The meeting is sponsored by Armour Research Foundation, American Industrial Hygiene Association, Acoustical Society of America, American Society of Safety Engineers, National Noise Abatement Council, American Society of Planning Officials, Acoustical Materials Association and Noise Control Magazine.

Address inquiries to Hale J. Sabine, Physics Research Department, Armour Research Foundation, 10 West 35th Street, Chicago 16, Illinois.

SHORT COURSES

THE DEPARTMENT OF INDUSTRIAL MEDICINE of the New York University Bellevue Medical Center Post-Graduate Medical School offers four courses in radiological health starting in November 1958. The courses are intended for persons already trained in one of the physical, engineering, biological or medical sciences who require a comprehensive introduction to the new techniques and methods associated with radiological hazard evaluation. The courses and times are: (1) Introduction to Radiological Health, full time, January 5-16, 1959, (2) Radiological Health Laboratory, full time, January 19-30, 1959, (3) Radiochemical Analysis, two-week intensive course, November 10-21, 1958, (4) Radiation Hygiene Measurements, four-week intensive course, May 4-29, 1959.

A two-week intensive course in community air pollution problems will be presented December 1-12, 1958, in cooperation with New York University College of Engineering. Toxicology of pollutants, micrometeorological factors, effects on agriculture and commerce, sampling and analyzing, methods of controlling effluents, and governmental regulations will be studied in relation to air pollution.

For further information on any of these courses write: Associate Dean, New York University Post-Graduate Medical School, 550 First Avenue, New York 16, New York.

Industrial Noise and Hearing Loss in a Controlled Population—First Report of Findings*

CHARLES D. YAFFE, HERBERT H. JONES, and EDWARD S. WEISS†

U. S. Department of Health, Education and Welfare, Public Health Service, Occupational Health Program, 1014 Broadway, Cincinnati, Ohio

FOUR YEARS ago at the Industrial Health Conference, we presented a description of a study which had just been undertaken by the Occupational Health Program of the Public Health Service for the purpose of obtaining some information about the relationship of industrial noise to hearing loss. It would be better to speak of this work as a number of concurrent studies, rather than as one study. We shall not review here the importance of the problem of industrial noise, but state merely that most of the questions concerning the subject are still not satisfactorily answered despite the large amount of worthwhile work which various investigators have performed in the interval.

The data reported here were obtained from studies conducted on workers in certain of the factories in Federal penitentiaries at Lewisburg, Pennsylvania, Leavenworth, Kansas, Atlanta, Georgia, and Terre Haute, Indiana. This study, which is still in progress, could not have been done without the complete cooperation of the U. S. Bureau of Prisons and the Federal Prisons Industries, Inc., and we wish to acknowledge our gratitude not only for their contributions, but the spirit in which they have been made.

Currently there is in preparation a detailed report of the findings for the first four years of this investigation. We are presenting here only a portion of the material to be included in that report.

The industries included in the studies and the approximate number of employees in each are as follows:

Lewisburg, Pennsylvania	
metal furniture, including steel shelving	360
clothing	60
Leavenworth, Kansas	
clothing	80
shoes	450
brushes	180

wood furniture	90
printing	40
Atlanta, Georgia	
cotton textiles	400
Terre Haute, Indiana	
woolen textiles	175

Total employment in these plants is approximately 1800. At the beginning of the studies, approximately 600 men were selected for periodic hearing tests. Those picked were chosen on the basis of the amount of additional time for which they were likely to be employed. Workers definitely eligible for release from the institutions in less than 18 months were not included in the original group to be tested. As men from the original study group were transferred out of the industries, they were replaced by newly assigned workers, so that the total number under study at any one time was relatively constant. The overall number of industry workers studied in the period included in this report is about 1600.

The workers in the group studied were given periodic audiometric tests. At the beginning of the study, all men were examined at 3-month intervals. Later the test schedule was modified so that testing was done 3 months, 6 months, and 12 months after assignment to a job and then annually thereafter.

Audiometric testing is done in acoustically treated test facilities located in the prison hospitals. Testing is performed, under the supervision of the Chief Medical Officer of each institution, either by medical technical assistants employed in the hospitals or by inmates assigned to hospital duties. The test procedures employed were established by Dr. Aram Glorig, who serves in a consultant capacity to the Public Health Service. Dr. Glorig personally provided instructions on audiometric procedures at the time that the study was started at each institution.

In addition to the hearing tests performed on the industry workers being studied, each of the institutions eventually incorporated an audiometric test into the physical examination per-

* Presented at the Industrial Health Conference, Atlantic City, N. J., April 22, 1958.

† Now with Allegheny County Health Department, Pittsburgh, Pa.

formed on all newly admitted inmates. Approximately 7,000 newly admitted inmates were tested during the period in question. Data obtained from these tests are useful not only for control purposes in evaluating hearing loss from noise exposure, but also for comparisons with other large populations which have been studied elsewhere by other investigators. Data from this group are also of value in comparing findings of one institution with those of another.

The numbers of newly admitted men tested in each institution were as follows:

Location	Number
Lewisburg	2108
Leavenworth	2539
Atlanta	1231
Terre Haute	1120
Total	6998

The number of new admissions tested each year was:

Year	Number
1953	631
1954	753
1955	1801
1956	2417
1957 (6 months)	1396
Total	6998

The median ages of men at Atlanta and Leavenworth are approximately 34 years compared to medians of about 25 years at Lewisburg and Terre Haute. This nine year difference is due to the types of institutions involved.

When the studies were begun, the question arose as to whether data obtained from one institution properly could be combined with data from others. Our original feeling was that they should not be combined since testing was not done under identical conditions in each institution. If data from different institutions could be combined, however, it would provide larger groups for comparisons. Often only a handful of men of a given age group with a given noise exposure are available in a single institution. In such small groups, there are serious limitations to the conclusions which can be drawn from findings about their hearing. The data from the various institutions were examined closely therefore to see whether such combining of data would be justifiable and acceptable for certain comparisons.

In a long term study of this nature, changes in personnel or equipment and other factors may exert an influence on findings, particularly if the testing is being performed at a number of geographical locations distant from the individuals having primary responsibility for the proj-

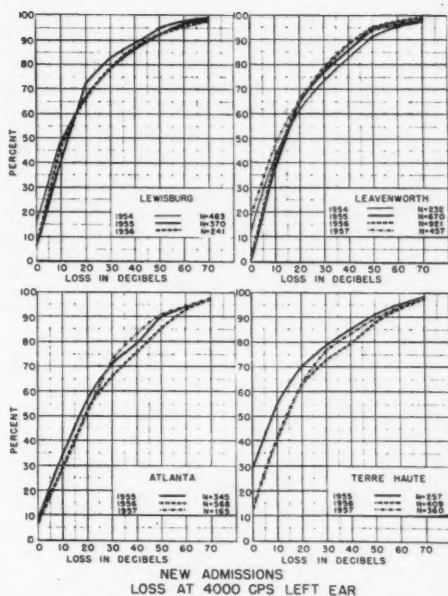


FIGURE 1

ect. An evaluation of these factors is not included in this paper.

The data from each institution were first examined for general consistency. This was done, as shown in Figure 1, by observing how much the distribution of hearing loss at 4000 cycles in the left ear varied from year to year. The curves show the cumulative percentage of individuals whose hearing loss did not exceed the indicated number of decibels. Loss at 4000 cycles was chosen because this is the point at which greatest loss most often occurs. The left ear was chosen because, on the average, left ears are found to show more loss. Where a single point is to be employed for detecting change in hearing due to noise, 4000 cycles in the left ear is the most sensitive index. While some variability is demonstrable through statistical tests, it was felt that, on the whole, each institution's results were reasonably consistent from year to year.

Figure 2 shows the distribution, at each institution, of hearing loss at 4000 cycles in the left ear for the total period of this report, classified according to age group. As would be expected, there is a progressive loss with age in each instance.

Figure 3 presents a comparison of the findings of all of the institutions for each age group. It is from an examination of this figure that the decision can probably best be made as to whether

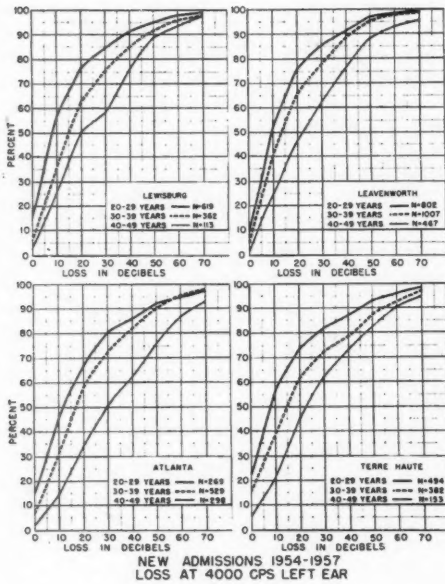


FIGURE 2

or not combining data of two or more institutions is a reasonable procedure.

With one minor exception which will be pointed out later, we have not combined data from the study groups of different institutions. However, the data on new admissions from the four institutions have been combined for use for control purposes. Specifically, we have taken the combined data for the four institutions at the 50% points as the median value for all new admissions in a given age bracket. For the comparisons which follow, we are concerned not only

with 4000 cycles in the left ear, but with six frequencies in each of two ears. Even with a combining of the new admission data, we have 12 sets of curves for each of the age categories as shown by the Figures 4 and 5 which follow. Figure 4, shows the losses by age in the left ear for 500, 1000, 2000, 3000, 4000 and 6000 cps for 6053 men whose hearing was analyzed.

Figure 5 gives the same data for the right ear. The numbers of men in each age bracket tested are as follows:

20-29 years	2184
30-39 years	2280
40-49 years	1031
50 and older	558

Figure 6 shows the median hearing loss by age for each ear in the different age categories. The consistent difference between left and right ears is readily apparent. The curves in this figure are the ones which will be employed in this paper for comparison purposes where hearing losses from noise exposures are presented.

Various other populations of comparable size have been studied in the past by other investigators. One was in the National Health Survey conducted by the U. S. Public Health Service in 1935 and 1936. The most recent published data of this sort were contained in the report of the studies conducted at the 1954 Wisconsin State Fair. In Figure 7, median losses in both ears for the 30-39 age group of our study are compared with those groups in the Wisconsin and National Health Survey studies. It will be observed that there are appreciable differences, with the prison population having the best hearing and the Wisconsin group the worst. This figure emphasizes that large variations can be found between different segments of the population. Figure 8, taken from the Wisconsin Re-

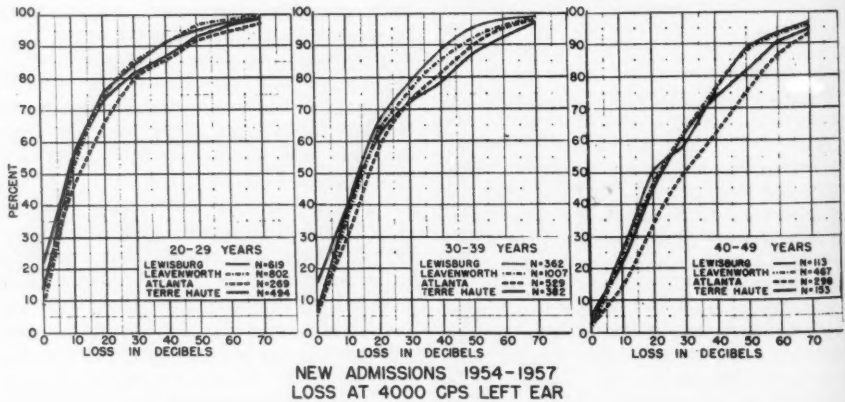


FIGURE 3

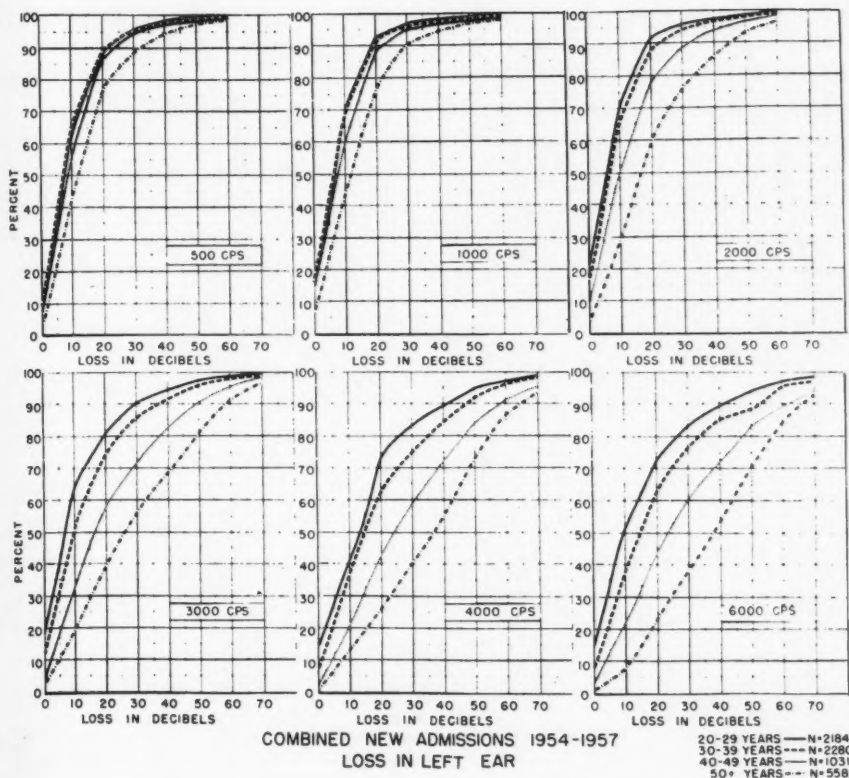


FIGURE 4

port, shows the influence of occupation upon hearing, as indicated by the lines representing office, farm and factory workers 30-39 years of age. To this figure we have added data from our study for the same age group, as shown by the curve labeled "New Admissions." One can observe that men admitted to Federal penitentiaries have hearing fairly comparable to that of the Wisconsin office workers. Officials of the Bureau of Prisons agree with our theory that a large proportion of the men admitted to the penitentiaries have probably not held steady employment for long periods and consequently have had comparatively little noise exposure.

The remainder of this paper deals with data obtained from serial audiometric studies on workers in various industries. Although we have considerable information on workers with longer periods of exposure the data presented here are limited to a maximum of one year of employment in a specific noise environment.

Since a number of different industries were included in these studies, a great variety of

noise environments were encountered. The range of total sound pressure levels extended from 70 decibels or less to 110 decibels or more. A wide range of sound frequency distributions were encountered and many types of sounds from intermittent impacts to continuous constant level sounds were found. It is generally believed that the nature of the sound as well as the overall sound pressure level must be taken into consideration in assessing potential effects of noise on the ear. In this preliminary examination of our data, however, it was felt that noise environments should be separated only into a few simple classifications. Consequently, they were divided first into either steady state or intermittent impact classes. Steady state noises were grouped in the six following ranges:

- 100-104 db
- 95-99 db
- 90-94 db
- 85-89 db
- 80-84 db
- Less than 80 db

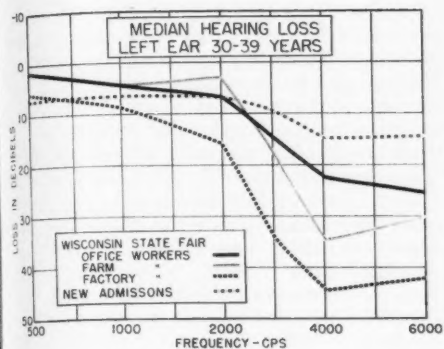


FIGURE 8

median age of men studied in this department was 34 years. The solid line represents the median hearing loss of 60 workers at the time of assignment to this department but before actually beginning work. Note that their loss was greater than that of the control group shown by the heavy dotted line. In classifying inmates for work in the prison industries, consideration is given to previous experience in given jobs. Bureau of Prison officials have advised us that many of the men assigned to the cotton mill have had previous experience in the textile industry. In other words, these men could have already suffered some hearing loss because of previous employment. Although not presented in this paper, our data indicate that the average

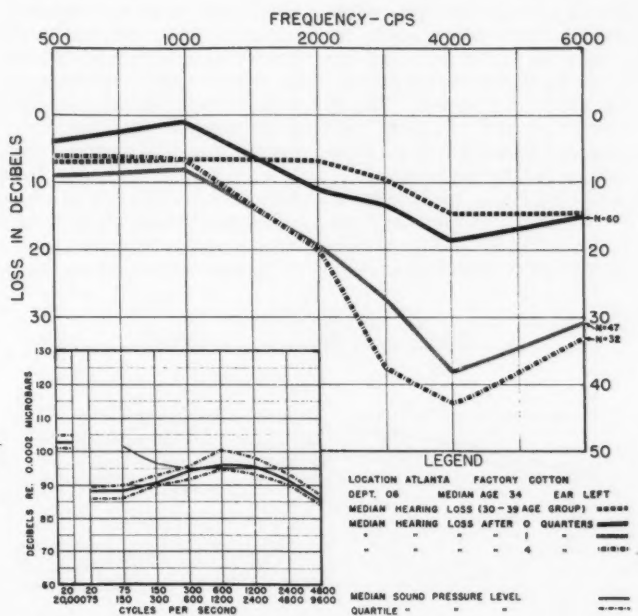


FIGURE 9

ing of groups of workers after three months and after one year of employment in the weave room of the cotton mill are seen in Figure 9. This department is in the 100-104 steady state category. The larger curves show the median hearing loss in the left ear of 47 workers at the end of one-quarter of a year employment in this department and the median loss in the left ear of 32 workers in this department after one year of employment. Also shown is the median hearing loss of all inmates between 30 and 39 years of age admitted to the four institutions. The

hearing loss of men to be assigned to noisy jobs is greater than that of men to be assigned to quiet jobs and that the noisier the impending job the poorer the initial hearing. This is attributed also to consideration of previous work experience in connection with job assignments.

As may be noted, a very considerable amount of hearing loss apparently develops even after only 3 months of exposure. In this instance, the loss after three months seems to be almost as great as after twelve months. It should be emphasized at this point, however, that these

losses and the others presented in this paper represent temporary and permanent losses combined. Additional studies, to be undertaken soon, may determine how much of this loss is permanent and how much is merely a temporary threshold shift. It has long been known that weavers have a noise-induced hearing loss. We believe therefore that an appreciable portion of the losses shown in this figure is permanent.

The noise to which these men were exposed was measured and analyzed in different locations within the department on a number of occasions. There were 587 looms in this department and the noise environment was essentially the same throughout. The solid line in the lower portion of Figure 9 indicates the median values obtained from all of the octave band analyses performed in this department over a 4-year period. The lines above and below it show the upper and lower quartiles of the data thus obtained. The short horizontal lines to the extreme left show the total sound pressure levels. It will be noted that the median value is 103 decibels.

The remaining curve, which appears on all of the figures which follow, is the well-known damage-risk criteria curve contained in the WADC Technical Report "Handbook of Acoustic Noise Control, Volume 2, Noise and Man" by Rosenblith, Stevens and the staff of Bolt, Beranek and

Newman. For those unfamiliar with that report, we would emphasize that its authors did not present those criteria as precise figures. When the criteria were proposed five years ago, it was stated that the contour should not be "...taken too literally since deviations of the order of 1 or 2 db in either direction could probably be disregarded. Contours such as these should be interpreted as zones with some uncertainty attending the measurement of the exposure stimulus, and biologic variability modifying the probability of damage. We feel, however, that contours 10 db lower would involve negligible risks indeed, while contours 10 db higher would result in significant increases in hearing loss." Other criteria which have been proposed in the interim do not differ markedly from these, which, significantly, were considered to be safe in terms of 8-hour daily exposures for a working lifetime, for noise that has a reasonably continuous time character with no substantial sharp energy peaks. Also these criteria were proposed, we believe, primarily to prevent appreciable loss in the speech frequencies, that is, those which lie below 3000 cps.

In view of these criteria, the fact that the median values in Figure 9 do not exceed the damage risk curve by more than 1 db at any point is of considerable interest.

Figure 10 contains similar data obtained on

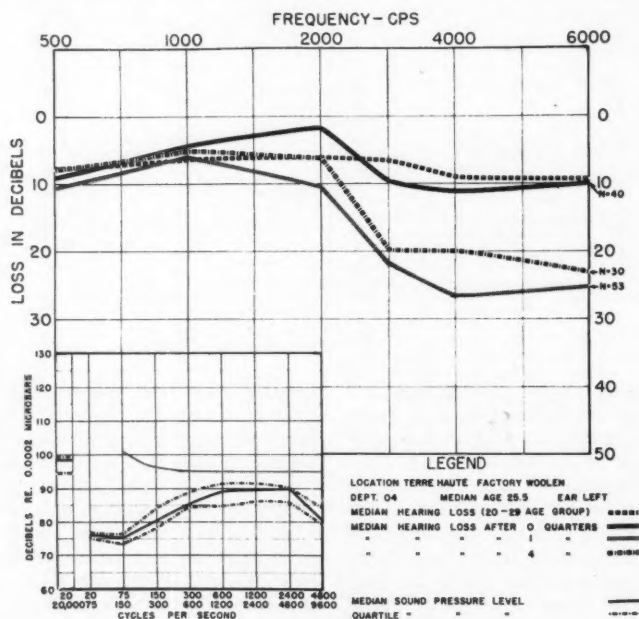


FIGURE 10

report, and not When it was taken of 1 or disre-inter- ending s, and 10 db while significant which differ were daily e that r with these re- quen- cps. the me- damage at is of ned on

testing the hearing of workers employed in the weave room of the woolen mill. The character of the noise exposure as determined by the octave band analyses was quite similar to that found in the cotton mill. The overall level was somewhat lower, however, the median value being 98 db or approximately 5 db less. This department had only 42 looms compared with 587 in the cotton mill. A slight peak was observed here in the 2400-4800 octave band areas. In the cotton mill the peak values were found at 600-1200 and 1200-2400. The hearing loss of workers in this department is apparently considerable although less than for the workers in the cotton weave room, particularly at 4000 cycles. The group of men tested after one quarter of employment shows a slightly greater loss than the ones tested after four quarters. It should be pointed out that not all of the men tested are to be found in each of the groups. This becomes apparent when one notes that there were 40 men in the preplacement group, 53 after one quarter, and 30 after four quarters. Note that the median octave band analysis is at least 5 db below the criteria curve at all points.

The data in Figure 11 were obtained on workers in the cotton mill employed in departments other than weaving. Most of these men were engaged in spinning and carding. The median over-

all sound pressure level to which this group was exposed was about 96 db, only 2 db less than the overall for the weave operation in the woolen mill and 7 db less than the weave operation in the cotton mill. The noise is seen to be concentrated more in the lower frequencies, particularly in the three octaves included between 150 and 1200 cps. The noise is the steady state type. Examination of the hearing loss curves indicates a much smaller median loss, less than 10 db, in the higher frequencies. The numbers of men tested were 90 in the preplacement group, 83 after one quarter and 46 after four quarters.

The next three figures are for operations in the woolen mill, exclusive of weaving. The first of these, Figure 12, is for men employed in dyeing, picking and finishing. Median overall sound pressure levels in these departments is seen to be 90 db with most of the noise, which was of steady type, concentrated in frequencies less than 600 cps. Examination of the audiometric data show only slight evidence, if any, of hearing loss after one year of exposure. Figure 13 includes workers in carding, spinning and maintenance. The overall noise level to which they were exposed was approximately 88 db with most of the sound concentrated between 150 and 1200 cps. The audiometric data give no indications of loss of even a temporary nature. Figure

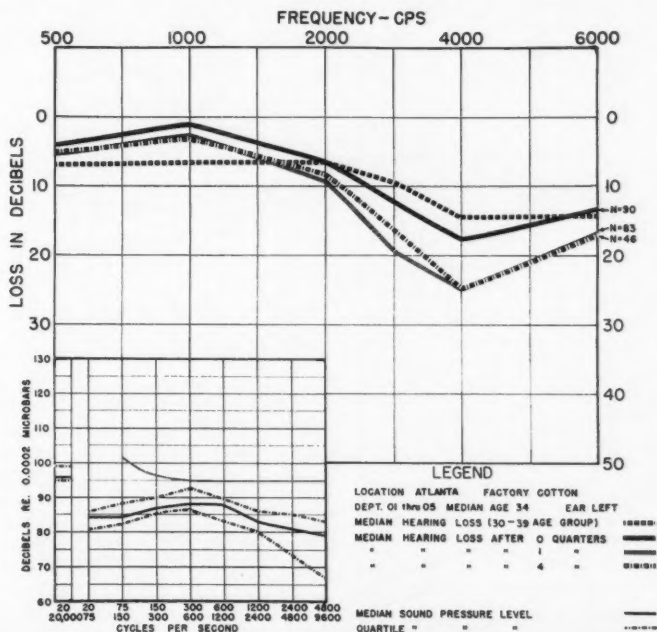


FIGURE 11

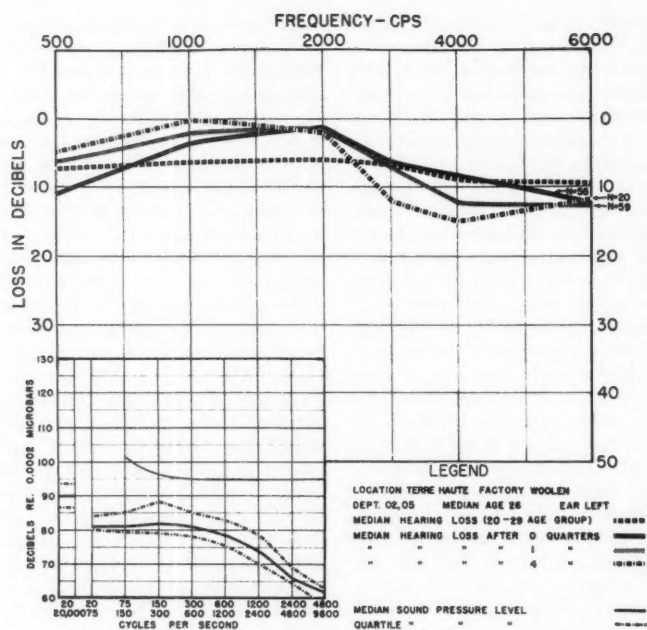


FIGURE 12

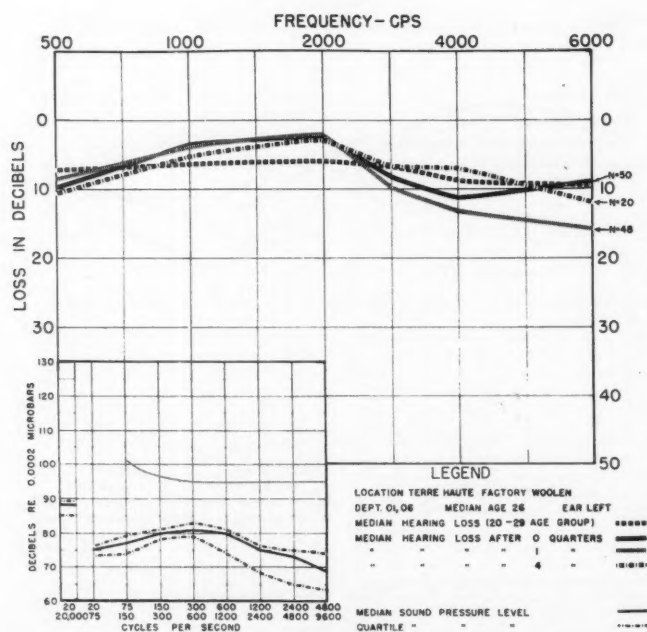


FIGURE 13

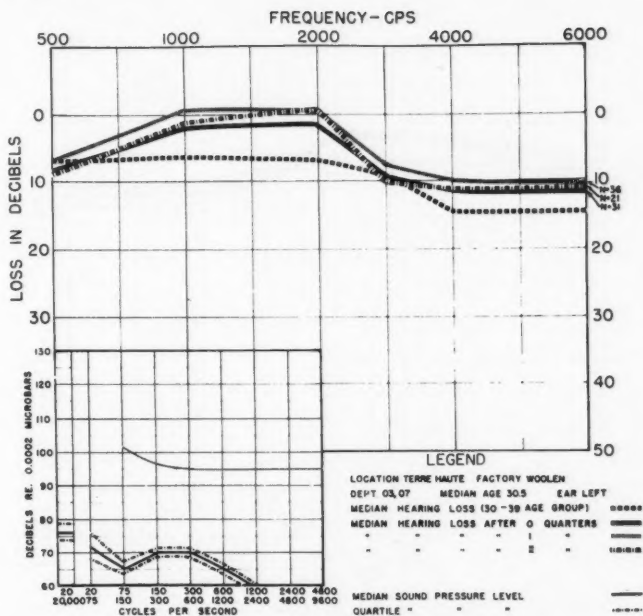


FIGURE 14

14 refers to the workers with still lower noise exposures. The overall sound pressure level to which they were exposed was less than 85 db. No signs of any hearing loss are observable in this group either.

Figure 15 combines the data from the three previous groups, in other words, all workers in the woolen mill outside of weaving operations. The median overall sound pressure level to which these workers were exposed was 88 db. These groups when combined show no signs of any hearing loss after one year of exposure. The numbers of men tested here were 136 preplacement, 143 after one quarter and 43 after one year.

Data obtained in wooden furniture manufacturing in the vicinity of planers and saws is plotted in Figure 16. The median overall sound pressure level is seen to be 100 db with the octave band analyses showing an essentially flat response except at the two ends. Unfortunately, the number of men employed at these operations was so small that very little data of statistical value were obtainable. The median hearing loss for 11 men having one year of employment in this environment is shown. Data on enough men were not available for the preparation of curves for other intervals of exposure. Only limited conclusions should be drawn from the results on 11 men. We shall merely point out that the median hearing loss values ob-

tained for this group resemble those obtained in weaving operations where the total sound pressure level was approximately the same.

The next two figures give the data obtained from workers employed in shoe manufacturing. Figure 17 shows data for men employed in the bottoming department and treeing and packing department. The median overall sound pressure level for these operations was approximately 94 db. Examination of the octave band analyses shows a slight peak in the 600-1200 cps octave band with much of the remaining energy in the two adjacent octave bands. Examination of the median hearing loss curves for workers in these departments shows nothing indicative of a hearing loss during the first year of employment. There were 17 men in the preplacement group, 26 with one quarter of exposure and 29 with four quarters.

Figure 18 includes the lasting, making, cutting, sole leather and welting departments. The sound pattern is very similar to that shown in the previous figure with the overall sound pressure level of 93 db being only slightly less. The audiometric data reveal a slight dip at 4000 cycles after 12 months of exposure, but there is no evidence of loss elsewhere. Seventy-six men were included in this group with 12 months of exposure. With a group this size showing this dip at 4000 cps, however, study of the effects of

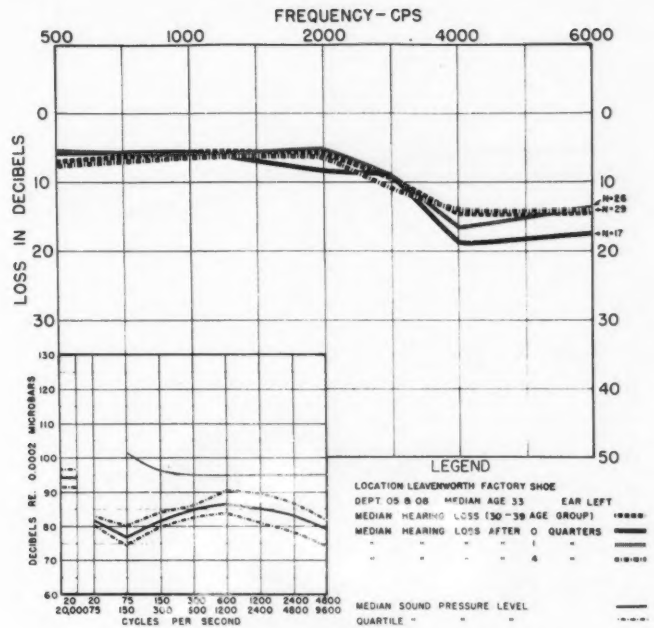


FIGURE 17

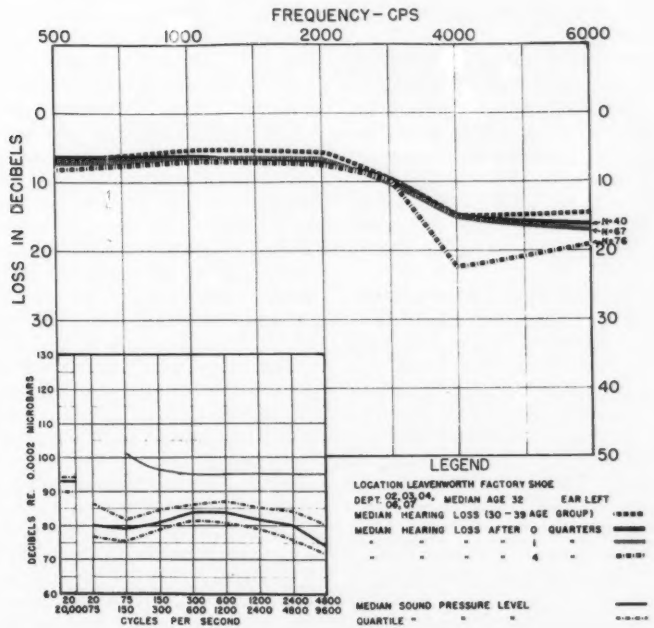


FIGURE 18

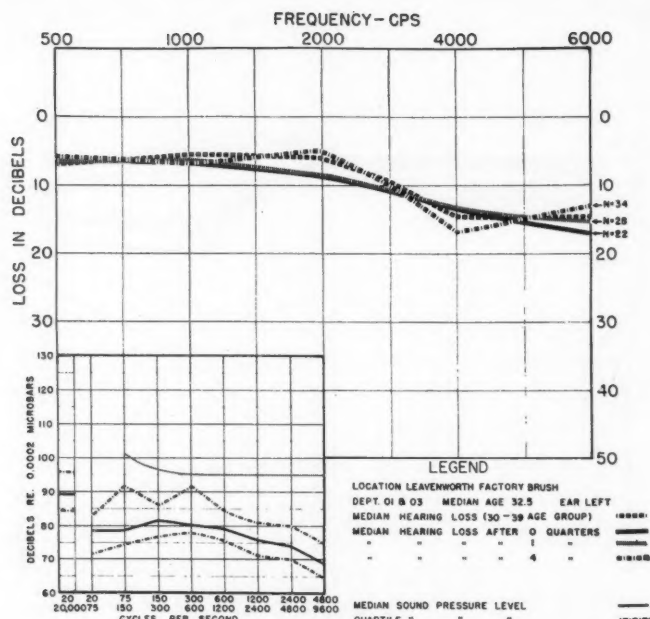


FIGURE 19

this environment over a longer period of time is indicated. Sixty-seven men with one quarter of exposure were tested and there were 40 in this preplacement group.

Figure 19 shows data obtained in connection with certain brush manufacturing operations. The median total sound pressure level in this case was just under 90 db. It will be noted that most of the energy was in the lower frequencies. The numbers of men tested in this area were 22 in the preplacement group, 28 after one quarter, and 34 after four quarters of exposure. No particular signs of hearing loss are to be seen in these groups.

The results in the next three figures were obtained in clothing manufacturing. Figure 20 is for the Lewisburg factory. The overall noise level here was 84 db with the energy peak being in the frequencies below 75 cps. The median age of the men in these operations was 25.5 years. The hearing of the study groups here was virtually identical with that of the new admissions of 20-29 years. The numbers tested were 25 in the preplacement group, 36 after one quarter and 29 after one year.

Figure 21 presents data for a similar factory at Leavenworth. The noise level and pattern is identical with that obtained at Lewisburg. Again, the hearing of the workers closely paralleled that of new admissions of the same age

group. The difference here from Figure 21 is that the median age of the Leavenworth workers was 38.5 years. The dotted line shown for comparison purposes, therefore, is the 30-39 year new admission group. The numbers of workers tested here were 17 in the preplacement group, 22 after one quarter and 27 after four quarters.

Figure 22 is the only one in which we have combined data on workers from two different institutions. Here we have combined the data shown in the two previous figures. The numbers tested were 42 in the preplacement groups, 64 after one quarter and 63 after one year. The median age of the combined groups of workers was 29 years. It will be observed that their hearing fits between that of the new admission groups of 20-29 years and 30-39 years of age.

The remainder of the figures deal with noise exposures of the intermittent, impact type. All of them involve operations in the manufacture of metal furniture, including steel shelving. The measurement of impact noises is difficult to accomplish. The assignment of a single decibel value which accurately depicts the weighted average exposure is even more difficult, particularly in a plant like the metal furniture factory at Lewisburg, since the types of products, as well as rates of production, may vary considerably from month to month. Despite the fact that the weighted average exposures assigned are under

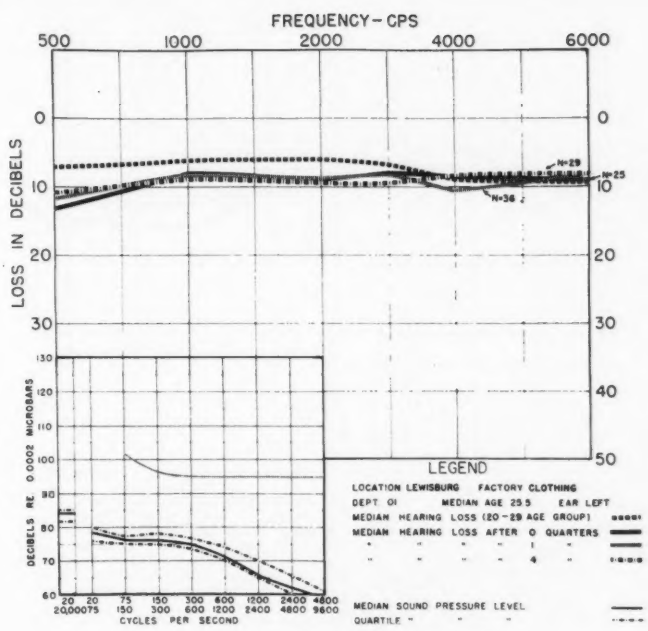


FIGURE 20

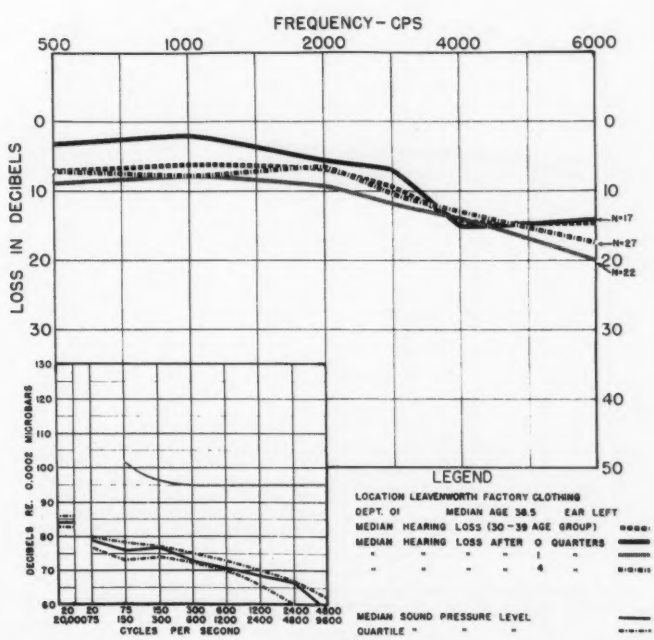


FIGURE 21

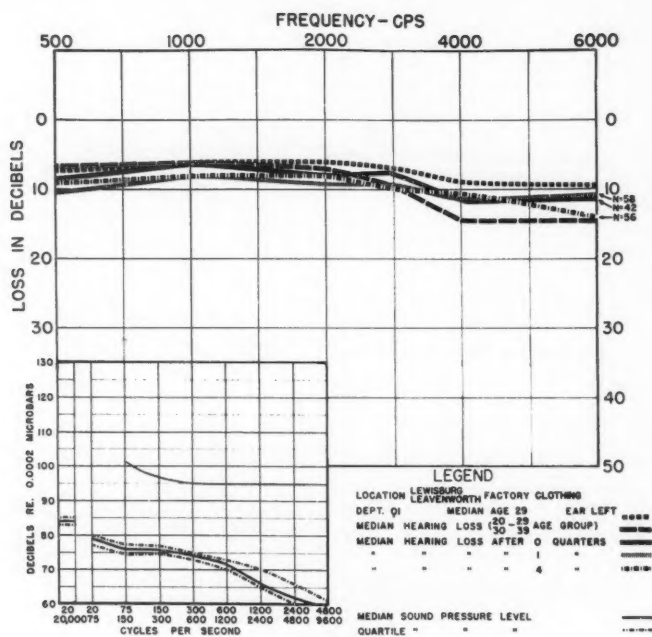


FIGURE 22

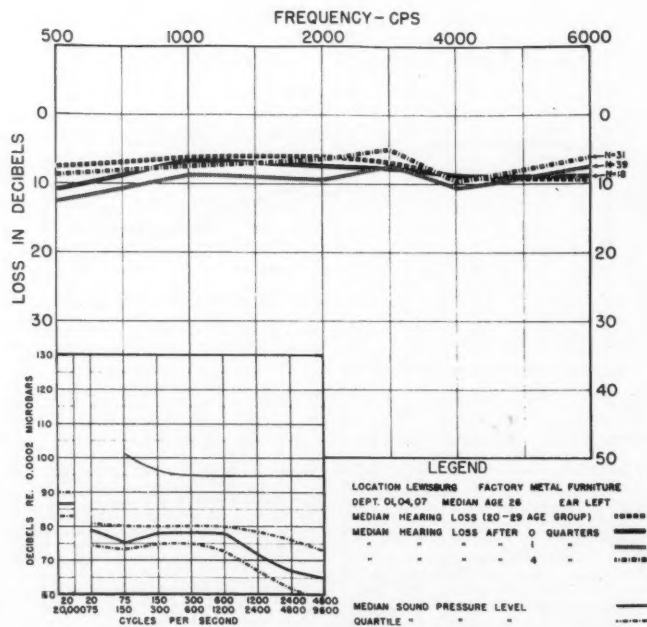


FIGURE 23

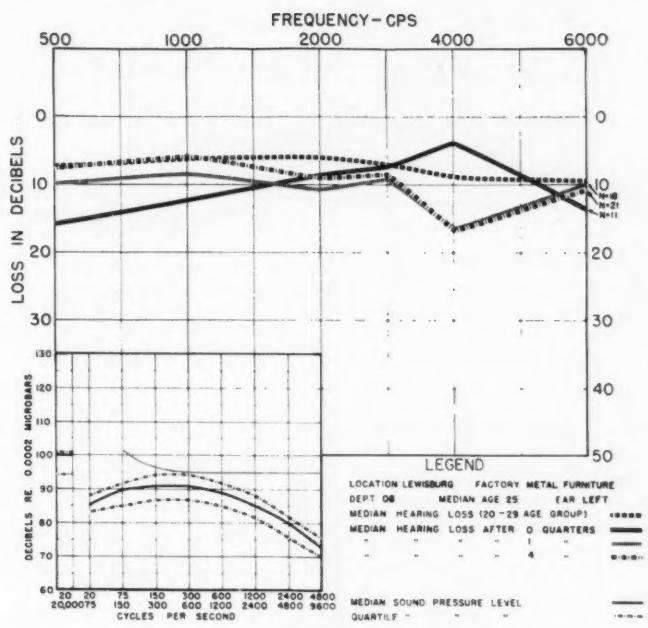


FIGURE 24

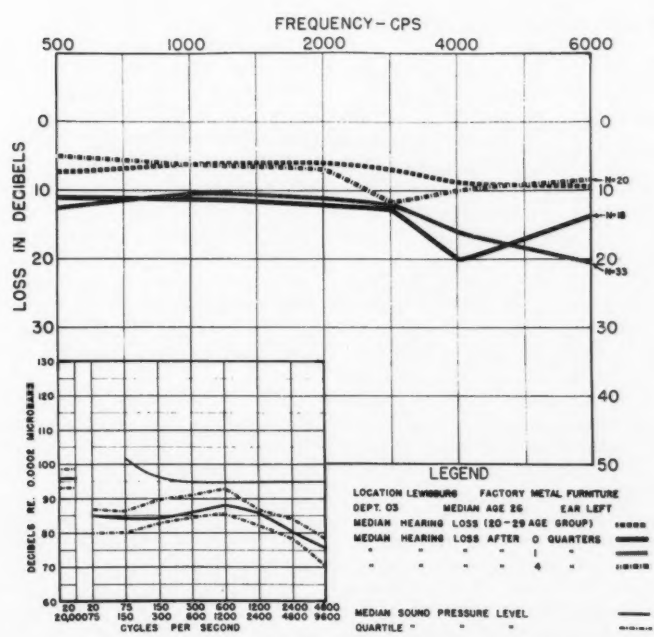


FIGURE 25

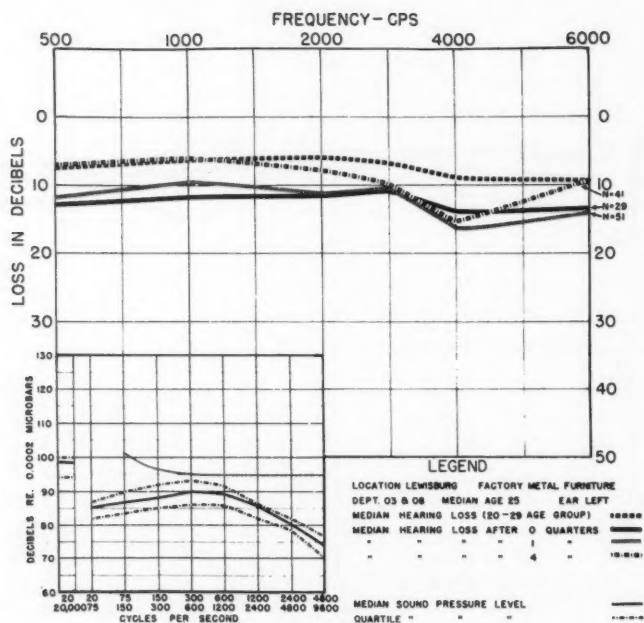


FIGURE 26

100 db, workers in these operations were frequently subjected to instantaneous peaks in excess of 125 db.

The operations are carried out on eight floors, each 60 feet by 200 feet, located in three buildings. Two floors are equipped with punch presses, shears, brakes, and lathes. Two floors have metal finishing, buffing, grinding, and maintenance. One floor is devoted to welding operations, including a spot welding assembly line. This factory usually consumes between 600 and 800 tons of steel per month.

As stated earlier we have attempted to divide estimated overall exposures in these operations into three general groups. Figure 23 shows results obtained on workers in assembly and warehouse work. The median overall noise level for these workers is shown as 86 db. It is readily apparent that no signs of hearing loss appeared among workers during their first year in these areas. The numbers tested were 18 in the preplacement group, 39 with one quarter of work and 31 with four quarters.

Figure 24 presents data from the shelving department. The median overall noise level assigned here was slightly under 95 db. There is some sign of a hearing loss at 4000 cps in the workers here. The numbers tested were small, however, there being only 18 after one quarter and 21 after one year. The preplacement group

contained only 11 men, which may explain the erratic shape of the solid line.

The data in Figure 25 is from the press department. The overall noise level here is not too different from that encountered in the shelving department. We assigned it a value of 96 db. The octave band analyses indicate a fairly definite peak in the 600-1200 cps octave. The shelving department noise was more concentrated in the 150 to 600 range. The audiometric data for press department workers are inconsistent. The 18 men in the preplacement group and 33 tested after one quarter of exposure showed hearing consistently worse, at all frequencies, than the new admissions in the 20-29 age group. Twenty men with a year of exposure did not show this loss.

Since the numbers of men in both the shelving and press departments were small and since both were exposed to intermittent impact noise of approximately 95 decibels we have combined the data for them in Figure 26. While this reveals a slight apparent loss, particularly at 4000 cps, we do not believe that definite conclusions are indicated here.

A detailed report of the overall findings is now being prepared. Hearing data for other work intervals should help us to draw some more definite conclusions, particularly if corrections for temporary threshold shift can be made.

Air Pollution Problems in Petroleum Refining*

FRANK J. ELLS

Socony Mobil Oil Company, Inc., Paulsboro, New Jersey

THE PETROLEUM refining industry was established in Delaware Valley many years ago and at that time the process was relatively simple and the quantity small when measured by today's standards. Socony Mobil's first operation in this area was begun more than forty years ago with a small refinery designed primarily to manufacture lubricants. As time passed, the requirement for petroleum products has multiplied many times in quantity and complexity to meet the changing demand. Associated with this change has been the increase in demand for large quantities of the light, volatile hydrocarbons. The recovery of petroleum products by simple fractionation has been replaced by a complex physical and chemical industry. This expansion and the importance and need of unrestricted use of natural resources has paralleled our growth in population. Accordingly, this change from a simple industry having minimum air and water pollution potential with a few neighbors to a complex industry having many neighbors has been gradual, yet large.

Socony Mobil, like other industrial enterprises located in our community, recognized its proper responsibility to these neighbors in fulfilling the requirements of being a good corporate citizen. Because of its concern for maintaining natural resources in the best possible condition, our Company published a policy which provided for minimizing and eliminating air and water pollution sources wherever practical.

Studies have been made by hygienists, chemical engineers, chemists, and other technically trained personnel to identify and measure these pollutants. This work has resulted in large investments being made to improve the retention and recovery of all petroleum fractions, new equipment to remove impurities from our water and air effluents and new procedures to minimize or eliminate the sources of pollution.

Air pollution problems of the Paulsboro Refinery which are to be reviewed during this discussion are classified as follows:

1. Evaporation from storage tanks,
2. Losses from processing units,
3. Effluents from furnaces and flares.

*Presented at the 1958 Industrial Health Conference, American Industrial Hygiene Assoc. Atlantic City, New Jersey, April 24, 1958.

Evaporation from Storage Tanks

Large quantities of crude, intermediate and finished products are commonly in storage at Paulsboro. About half of these materials have sufficient vapor pressure at storage temperatures to pose an evaporation loss and air pollution problem.

Pressure-type vessels are used for storing products having vapor pressures above that of the atmosphere (butanes-butylenes, propane-propylene, etc.). Vapors escape from such tanks only in emergencies when relief valves operate to protect the tank from excessive pressure. This type of tank is very expensive and its use, therefore, is restricted.

A variety of tanks are used for storing products of moderate volatility such as gasolines, naphthas, and crude oils. Figure 1 illustrates the relative efficiency of several common types.

Most of the motor gasoline storage tanks are equipped with floating roofs. A few are cone-roofed tanks equipped with conservation vents. In order to reduce the loss and air pollution from these cone-roofed tanks, the installation of floating roofs is being considered. Another possibility under consideration is the installation of a new tank equipped with a lift roof and connected to the cone-roofed tanks by means of vapor lines.

Crude oils are stored in cone-roofed tanks equipped with conservation vents. Microballoons have been installed in several tanks used for the storage of relatively volatile crude oils. (Microballoons are tiny hollow plastic spheres which are filled with an inert gas. They form a floating layer on top of the crude oil and retard evaporation.) The efficiency of Microballoons in reducing evaporation is illustrated in Figure 1 and is based on our experience with their use on crude oil having a vapor pressure of eight pounds Reid. Use of Microballoons is being extended to crude oils with lower vapor pressures.

Losses from Processing Units

At processing units, volatile and gaseous materials may be discharged to the atmosphere or to flares from a variety of sources. At Paulsboro, all of the units have been surveyed and the active and potential sources of pollution

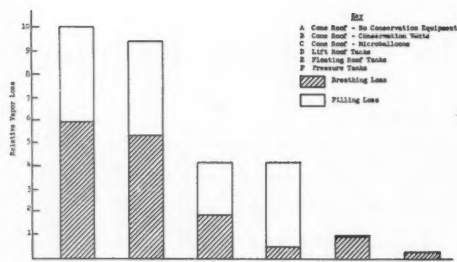


FIGURE 1. Relative evaporation loss from petroleum storage tanks.

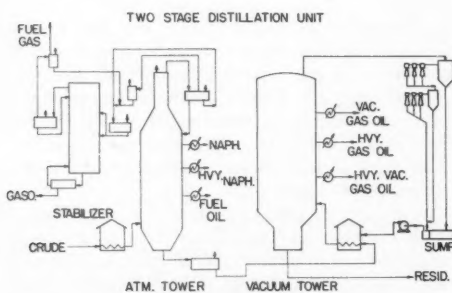


FIGURE 2

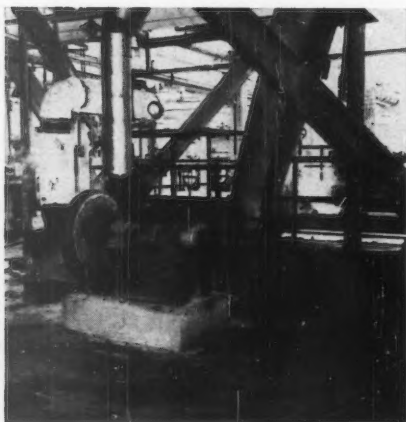


FIGURE 3. Blower and duct installation—Barometric sump.

identified. Several sources of pollution detected during surveys have been selected for comment.

VACUUM JET DISCHARGE

A survey of one of our two-stage crude distillation units disclosed that substantial quantities of hydrogen sulfide and hydrocarbons were

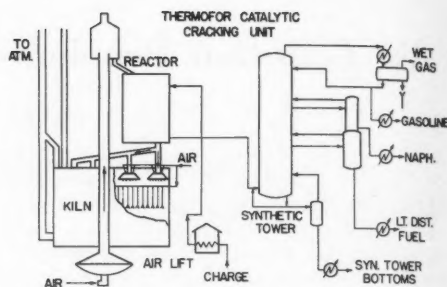


FIGURE 4

being vented to the atmosphere from the vacuum system. A schematic flow diagram of this unit is presented in Figure 2. The second stage tower is operated under vacuum to enable distillation of the heavy oils below the cracking temperature. The vacuum system consists of a barometric condenser with two stages of steam jets. The non-condensable gases were discharged to the atmosphere. Study of this problem revealed that the pollution could be eliminated by hooding the sump and conducting the gases to one of the unit furnaces by means of a blower and duct system. The system has been installed and is controlling this source of pollution. Figure 3 is a picture of the blower and duct installation.

PLUME FROM CATALYTIC CRACKING UNIT

A flow diagram of a Thermoform Catalytic Cracking Unit (T.C.C. Unit) is shown in Figure 4. In this unit, heavy boiling fractions are cracked to produce gasoline and home heating fuel. In the cracking process, the catalyst is impregnated with coke and heavy oils which are removed in the kiln. Formerly, the spent catalyst was contacted, in the upper section of the kiln, with hot flue gases which stripped some of the heavy oil from the catalyst and discharged it to the atmosphere as a visible plume. (See Figure 5.) The upper section of the kiln was modified so that air could contact the catalyst as it entered the kiln. This allowed combustion of the heavy oil and practically eliminated the plume. (See Figure 6.) Figures 5 and 6 are photographs taken on the same day during an evaluation test of the plume burner when process conditions were adjusted to produce a heavy plume. In Figure 5 the plume burner was not operating, whereas in Figure 6, it was.

DISPOSAL OF HYDROGEN SULFIDE

Hydrogen sulfide is formed from sulfur contained in crude oils in substantial amounts in

certain refinery operations and presents serious process and disposal problems. The handling of products from a T.C.C. Unit illustrates these problems. Thus, gases and gasoline from this unit flow to a gas plant for recovery and fractionation. Referring to a flow diagram of the gas plant (Figure 7), the bulk of the hydrogen sulfide is removed from the wet gas by scrubbing with a di-ethanol amine solution and is presently burned at a high level flare. A plant is being built which will produce elemental sulfur from this and other streams of recovered hydrogen sulfide.

Hydrogen sulfide present in the propane-propylene and butane-butylene streams is removed by scrubbing with caustic soda. This waste material is used as a process chemical by other industries.

Water resulting from condensed stripping steam contains considerable quantities of hydrogen sulfide. Because ammonia is formed in the cracking operation, much of the sulfide is in the form of ammonium sulfide. This water which is discharged to the refinery sewer system from the gas plant is known as sour water. Hydrogen sulfide is released from this water if it contacts acidic water in the sewer system. A sour water oxidizer has been designed and construction is planned this year. In this unit, the sour water will be contacted with air and the sulfides oxidized to thiosulfates and sulfates. It is expected that this installation will reduce both air and water pollution.

FUMES FROM THERMOFOR CLAY BURNER

Filter clay which is used in decolorizing and finishing lubricating oils and special products is regenerated in Thermofoor Clay Burning Kilns at Paulsboro. A flow diagram of one of these kilns is presented in Figure 8. The clay is fed into the top of the kiln and is contacted counter-currently with hot air. At the top of the kiln, the flue gases are essentially oxygen-free and strip oil from the clay. Formerly the flue gases were passed through a cyclone separator which removed most of the clay from the gases but allowed the oil to be discharged to the atmosphere as a fog. A two-stage scrubber using water as the scrubbing medium was installed. This unit removes about 95 per cent of the oil mist and all of the clay formerly discharged to the atmosphere.

Effluents from Furnaces and Flares

FURNACES

Refinery processes often require heat of reaction and many involve distillation for either

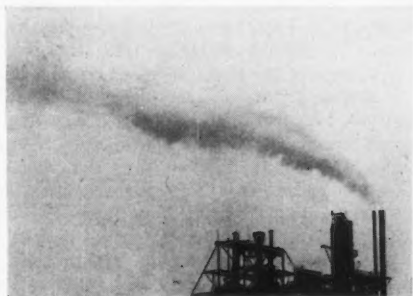


FIGURE 5. Airlift TCC plume (plume burner off)

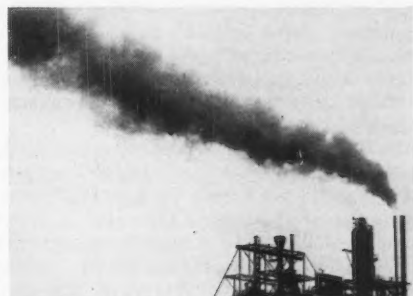


FIGURE 6. Airlift TCC plume (plume burner on)

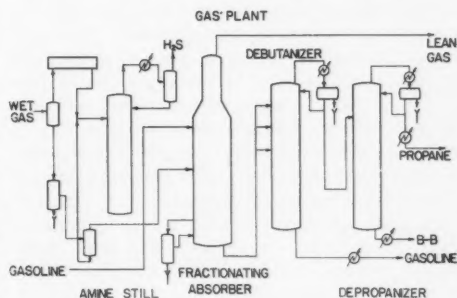


FIGURE 7

T C B KILN & SCRUBBER

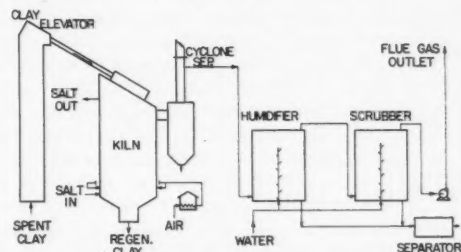


FIGURE 8

product fractionation or recovery of refining solvent. As a result, practically all units have furnaces or depend on steam from the power house to supply the necessary heat. Smoke may be a major pollutant resulting from furnace operation. In general, it is a visible sign of inefficient operation. Properly designed fuel oil systems and combustion controls will greatly reduce smoke incidents. For efficient operation, the temperature of liquid fuels must be controlled so that their viscosity at the burner is low enough to assure complete atomization.

Combustion controls on process furnaces are relatively simple because the load is relatively constant. The fuel flow to the furnace is controlled by instruments which are set to maintain the furnace outlet temperature at the desired level. Dampers are set manually to provide optimum conditions. Combustion efficiency checks are made on a regular basis and adjustments made when necessary.

At the power house, the situation is different because the load fluctuates and both gaseous and liquid fuels are burned. In addition, fluctuations in the fuel gas supply are absorbed. In all, five different fuels are burned. The combination of fluctuating load and variable fuel supply makes a complex control system necessary. These controls automatically adjust the fuel rate to maintain a constant steam header pressure giving first priority to available gas. The controls are essential to economical operation of the boiler furnaces and for this reason are reviewed periodically to assure optimum performance. Recently, the air-fuel ratio controllers on the boilers were modified to speed up the response of the instrument to demand changes. Besides improving fuel utilization, the change also reduced smoke incidents.

In order to guard against smoke conditions, haze detectors are installed in the flues of all boilers. These detectors are connected to re-

corders and alarms so that the operators are promptly alerted to smoke conditions.

FLARES

As at all refineries, flares are required to safely dispose of excess fuel gas. Under normal conditions, all of the gas except that used in the flare pilots is burned under process or boiler furnaces. However, conditions occasionally arise when the quantity of gas produced is greater than can be burned under the furnaces and must be flared in order to prevent its escape to the atmosphere. There are two flares at Paulsboro. One flare is 150 feet high and the other 250 feet. They have special tips equipped with steam aspirators and are designed to permit smokeless combustion except under extreme conditions.

Summary

Growth in size and complexity of our petroleum industry has paralleled that of the increased population. Today, Delaware Valley is one of the major refining centers of the United States and petroleum refining is an extremely important factor in the economy of this region. Because of the nature of this operation, where size and location are easily identified, adverse public opinion has been leveled at the industry generally. During the past five or ten years, few enterprises have accepted their responsibility as good corporate citizens in as serious a manner as the oil industry. Tremendous technical effort has been directed to the development of methods to minimize and combat air pollution. Substantial investments have been made in equipment to achieve these objectives. These studies have been made in cooperation with technical representatives of public and governmental organizations. All have combined to develop and establish practical controls for adoption by industry to provide an unpolluted atmosphere for our area.

ACOUSTICAL SOCIETY MEETING

PAPERS in the fields of Architectural Acoustics, Audio Engineering and Electro-Acoustics, Noise and its Control, Shock and Vibration, Sonics and Supersonics and related topics will be presented at the forthcoming 56th Annual Meeting of the Acoustical Society of America to be held at the Congress Hotel, Chicago, Illinois on November 20, 21 and 22, 1958.

Additional sponsoring organizations include the Chicago Acoustical and Audio Group and the Chicago Chapter of the Professional Group on Audio of the Institute of Radio Engineers. An exhibit of materials related to acoustics will be held.

Chairman of the sessions will be William M. Ihde, General Radio Company, and Vice-Chairman, Robert W. Benson, Armour Research Foundation. Howard C. Hardy of Howard C. Hardy, Consultants in Acoustics, is Chairman of the technical papers committee.

A Review of the Pneumoconiosis Problem in the United States*

HENRY N. DOYLE,[†] ROBERT H. FLINN, M.D.,[‡]
and W. C. DREESSEN, M.D.[§]

PNEUMOCONIOSIS, and more particularly silicosis, has been the outstanding occupational disease disability problem of American industry for many years. It was of such magnitude that, for the period 1914 to 1940, most of the effort of the Industrial Hygiene Division of the Public Health Service was devoted to pneumoconiosis research; in this effort, many co-operative studies were done with the U. S. Bureau of Mines.

Although the basic research era began in 1914, it was not until 1924 that instrumentation and diagnostic procedures had developed to the point where environmental conditions could be correlated with pathologic findings. With the development of the impinger and the mobile x-ray unit the Public Health Service in 1924 embarked upon a series of epidemiologic studies that culminated around 1940.¹⁻¹⁰

By this time, three disabling types of pneumoconiosis had been recognized—silicosis, with and without complicating tuberculosis; anthracosilicosis; and asbestosis. The etiology, epidemiology, pathology and methods of prevention had been well defined, and it was believed that, through the application of developed engineering and medical principles, pneumoconiosis could be prevented. The period 1935 to 1940 also was one in which industry began to apply these developed preventive techniques on a very wide scale. This research had led to certain conclusions regarding the pneumoconioses,¹¹ which need not be repeated at this time; however, attention is directed to two conclusions: (1) that some nonsilica components in industrial dust, especially iron oxide, may prevent or modify the action of silica in the body and may alter the tendency toward complicating tuberculosis; and (2) that asbestos was the only dust other than free silica that had been shown to cause a lung

fibrosis with disability. Anthracite dust containing free silica had been found to produce a disabling lung fibrosis called anthracosilicosis, but bituminous coal was not viewed as a serious pneumoconiosis problem.

Beginning in 1940 there was decreasing emphasis on pneumoconiosis research. This period might be regarded as one for determining whether the accepted preventive techniques were, in fact, adequate. Several new diseases were also described that would cast doubt on the validity of some developed concepts of pneumoconiosis. For example, Shaver's disease dramatized the possible role of ultramicroscopic particles in the production of pulmonary disease.¹² British research reopened the question of the toxicity of coal dust; berylliosis, although not accepted as a pneumoconiosis, presented a different concept of the reaction of lung tissue to toxic dust, and some investigators questioned the relation of pneumoconiosis to lung cancer.

With this background the Public Health Service in 1954 began reevaluating the pneumoconiosis problem in the United States. The study of the prevalence of silicosis, together with the collection of data on compensation cost, a re-study of the silicosis problem in the Vermont granite sheds, and the gathering of information on some new disease problems, constituted the first steps in the reevaluation.

Prevalence of Silicosis

The Trasko study on the prevalence of silicosis was reported at the 1957 Industrial Health Conference, so at this time it is necessary only to give a few highlights of that study.¹³

Covering the 5-year period, 1950-1954, the study found 10,362 cases of silicosis that had been compensated or reported in one form or another in the 22 States from which data were received. If cases processed by compensation agencies but for various reasons denied benefits were added, the total would exceed 13,000.

Because of the difficulties surrounding the gathering of these data, and because of the limitations inherent in the records themselves, there is reason to believe that the 10,362 cases

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[†] Assistant Chief, Occupational Health Program, Public Health Service, U. S. Department Health, Education and Welfare, Washington, D.C.

[‡] Chief, Division of Health, Bureau of Mines, U. S. Department of Interior, Washington, D.C.

[§] Deputy Medical Director, Bureau of Employees Compensation, U. S. Department of Labor, Washington, D.C.

underestimate the actual situation. Nonetheless, one cannot deny that even 10,362 cases, in 22 States are a sizable number, even if distributed over a 5-year period.

The data reveal that these cases represent primarily an older group, three-fourths of the cases uncovered being in individuals over 50 years old. This finding, within limitations imposed by the data, supports the current opinion that many cases of silicosis coming to light at present represent a residue of old cases; however, these data also show that silicosis is occurring among young men with recent exposures.

Compensation Costs

The most forceful evidence that silicosis is a continuing problem lies in what the disease is costing society today. For that reason, the Trasko study on the prevalence of silicosis was supplemented with cost of compensation.²⁴ For 9,800 cases on record between 1950 and 1955 in 18 States the compensation cost amounted to \$43,700,000. This amount covers benefits paid on open cases up to 1954 or 1955 and awards allowed or paid in death cases. When allowances are made for incompleteness of information and for costs in other States for which data are not available, compensation costs of silicosis cases outstanding since 1950 can be estimated to amount to at least \$10 million per year. In contrast, the budgets of official industrial hygiene agencies for the entire country amount to less than \$3 million annually. It is these agencies in which responsibility is vested for controlling and preventing not only silicosis but also all other occupational diseases.

Revaluation of Silicosis in the Vermont Granite Sheds

The value of dust control in preventing silicosis has been clearly demonstrated in a recent study of silicosis in the granite sheds of Barre, Vermont, where a continuous environmental control and x-ray program had been in effect since 1937.²⁵ This study sought to determine the effectiveness of the control measures that had been established as the result of a study of the granite cutting sheds by the Public Health Service in 1924 and 1938. The earlier study had revealed an almost universal occurrence of silicosis in workers who had been exposed for 10 years or more to concentrations above 40 million particles per cubic foot of air (mppcf). Between 1935 and 1937 practically the entire Vermont granite cutting industry adopted dust control measures.

The 1956 study,²⁵ including an examination of

past records, indicated that few exposures in the industry exceeded 5 mppcf after dust control measures were adopted. In evaluating the Vermont problem, 1937 was taken arbitrarily as separating pre-control and dust-control periods. A total of 1,112 workers in the study group gave histories as having started work in the granite industry before 1937 and 1,134 in 1937 or after. Silicosis was diagnosed in 538 or 40 per cent of the men employed before 1937. The average number of years of employment for the men with silicosis was 32.4 and for the men with no silicosis 26.3. At least two-thirds of the affected men had already worked 30 or more years. On the other hand, no silicosis has been found in the group of 1,134 men who started work in the granite industry in 1937 or later. This experience tends to support the adequacy of the standard of 5 mppcf and indicates that, with proper engineering controls, the disease can be prevented. It is possible, however, that with better controls the time for development of the disease has been extended beyond the 20-year span covered by this study.

Some New Disease Problems

The theory of action of dust, especially silica, on human tissue has been the subject of much research, and new concepts are constantly being developed. These new concepts might aid in explaining the occurrence of certain recently recognized pneumoconioses, especially coal pneumoconiosis.

The theory of solubility, as an explanation for the pathogenicity of dust, has completely replaced the one of mechanical irritation. This theory, in simplified form, held that silica particles in contact with tissue slowly dissolved and brought a toxic substance into contact with the tissue, causing a fibroblastic reaction. More recently King,^{26, 27} in connection with his Medical Research Council studies, has critically reviewed the solubility theory. After allowing that silica may act differently in the body than in a test tube, he proposes that the silica released from particles of pathogenic siliceous dust may be nascent. This special fibrogenic property comes into play when the silica dust particle is in contact with the protoplasm of the cell. Hefferman²⁸ too, stressed physio-bio-chemistry when he advocated surface activity on the part of aerosols as being harmful to tissues; he has held that the essential causative agent of true silicosis, as distinguished from nonspecific pneumoconiosis, is the freshly cloven silica particle.

Through the years there have been various *in vitro* and *in vivo* experimental studies that have

varying degrees of clinical or general application. General clinical observations had suggested that some dusts had antidotal properties when inhaled with free silica. Clinical and pathologic studies had suggested that inert dusts such as coal and iron ore moderated the reaction of the lungs to inhaled quartz dust.

King, according to C. M. Fletcher,¹⁹ feels that dusts might be divided into three groups according to pathogenicity. The first includes silicogenic dust, containing free silica, in which there is no antidotal substance and which produces collagenous fibrosis. The second group comprises siliceous but less silicogenic dusts, which usually are a mixture of free silica with some antidotal substance, such as kaolin, mica, and shales, or natural solid mixtures, such as granite, which consists mainly of feldspar, mica, and quartz. The third group is that of nonsilicogenic dusts, containing very little or no silica at all, which are inert by themselves. These include coal and pure graphite.

King's experimental work had shown that the nonsilicogenic dust, including coal, may potentiate the effect of a small amount of silica. Thus, if small quantities of quartz were mixed with coal, which by itself is nonfibrogenic in animals, it appeared as if coal delayed the sweeping out of the lungs of the quartz into the lymph glands, and fibrosis could be produced in injection experiments.

Lung Disease in Coal Miners

Notwithstanding the theories on the pathogenicity of coal dust, pulmonary diseases have been, for many years, an important problem in large segments of the coal mining industry. The severity of this problem has varied considerably from one mine to another and from one coal bed to another, depending to a large extent on the geology of the coal bed, the methods of mining, the quantity and quality of respirable dust produced, and the length of exposure.^{20, 21}

There has been considerable confusion in the literature regarding pneumoconioses produced by coal mining, including the terminology, the exact nature of the underlying pathology, x-ray interpretations, and evaluation of disability.

At present, however, there is growing agreement as to the terminology of lung pathology resulting from exposure to coal dust. The term anthracosis means merely a blackish pigmentation of the lungs caused by deposition of carbon particles and may be observed with no evident pathology at autopsy even in city dwellers who have had no industrial exposure. Since no apparent pathology or disability is associated with

this deposition of pigment, anthracosis will not be considered further here.

The term anthracosilicosis generally means a modified form of classical silicosis resulting from prolonged exposure to coal dust and to rock dust containing significant amounts of free silica (SiO_2), in addition to coal dust. This disease was described in a study by the Public Health Service in the anthracite mines of Pennsylvania, where considerable work is done in hard rock.²² The pathology observed in these cases was essentially deposition of coal dust in the lungs, accompanied by an extensive fibrosis, both diffuse and nodular, with associated functional and degenerative changes.

The term coal workers' pneumoconiosis, however, as described by the British and a few writers in the United States,^{23, 24} is a different disease because there is little or no evidence of classical silicosis or of significant silica exposure. This disease, caused by coal dust itself, according to British investigators, is an established entity. They believe that it is similar in all coal mining areas, based upon their own studies and reports from other coal-producing countries. They state that, although the pathologic lesion appears to be the same everywhere, this does not mean that simple pneumoconiosis occurs as frequently or progresses as rapidly in all coalfields, since the quantity and quality of the coal dust vary. They also conclude that in some coal miners, who have done drilling and boring and have been exposed to silica dust underground, features of true silicosis may be combined with features of pure-coal workers' pneumoconiosis, and all stages between these two diseases may be found. American experience would tend to support this conclusion. This situation would naturally vary among different geologic formations.

The diagnosis of coal workers' pneumoconiosis in life depends basically on x-ray changes, accompanied by symptoms and the industrial history. Until simple pneumoconiosis becomes complicated by infection, usually tuberculosis, which is known as progressive massive fibrosis, these are little clinical evidence of disability.

The British studies indicated a high prevalence of chest abnormalities detectable radiologically among the coal miners and demonstrated that the changes were not typical of silicosis. The largest number of cases occurred among those working at the coal face but also showed among coal trimmers who were presumably exposed principally to coal rather than rock dust. According to Gilson,^{25, 26} much work on the pathology indicated that the disease is pathologically distinct from silicosis. The lungs contain large quantities of coal dust that is aggregated into

foci surrounding the respiratory bronchioles. The fibrosis produced is strikingly sparse, the coal dust being held in a fine mesh of reticulin fibrils, stellate in appearance, and it contrasts greatly with the rounded whorled nodule of silicosis. The pathologic process seemed to be the same in whatever coal-field the men had worked. The disease has two forms, simple pneumoconiosis, characterized by multiple coal foci scattered throughout the lungs, surrounded by small areas of emphysema (focal emphysema); and progressive massive fibrosis, the advanced complicated form starting as a collagen fibrosis within a few coal foci, which subsequently enlarge and coalesce to form a dense mass of fibrous tissue. This fibrosis may occupy much of a lobe or even a whole lung, and is thought to be due to tuberculosis superimposed on a lung heavily laden with coal dust.

Experience in United States

In the United States limited information developed mainly by private clinics has indicated that coal workers' pneumoconiosis, or at least a similar pulmonary condition, exists among coal miners in various sections of this country. This conclusion is based on clinical observations only. The environmental conditions and contaminants that cause or contribute to the disease and the prevalence of the disease among coal miners have not been studied in recent years. In the 1933 Public Health Service study of anthracosilicosis among miners in the anthracite field, and, on the basis of examination of 2,711 employees of three mining companies, it was concluded that 23 per cent of these men were affected in varying degree.²²

The correlations between exposure to dust and the evidence of constitutional changes left little doubt as to the etiologic significance of the dust in the air breathed. Likewise, correlations were found between the silica exposure and the extent of pulmonary changes.

A similar investigation in the bituminous industry by the Public Health Service in 1939 was limited to environmental surveys in three mines in Utah and medical examinations of 545 employees at these mines.²³

After ruling out 38 workers who had had dust exposures other than coal, anthracosilicosis, as shown by x-ray changes, was found in only 16 (3.2 per cent) of the 507 bituminous-coal-mine workers. Fifteen of these 16 workers showed evidence of first-stage anthracosilicosis with but little disability; one worker showed evidence of second-stage anthracosilicosis with moderate disability; and in no instance was third-stage anthracosilicosis found with severe or total dis-

ability. Anthracosilicosis was found only in workers whose principal occupation was underground, no case being found among tipple or other surface workers. Thirteen cases occurred among men working at the face and three cases occurred among transportation workers. The incidence of anthracosilicosis among the 348 underground workers was 4.6 per cent. Since pathologic studies were not made, it is possible, in view of our present knowledge, that these cases may have been coal workers' pneumoconiosis.

Thus, it is evident that only very limited information has been developed in the United States on the effects of the working environment upon the health of bituminous coal miners. It is important that more investigative work be done to determine the significance of pneumoconiosis among American coal miners.

Diatomaceous Earth Pneumoconiosis

Another dust disease that has come into prominence in recent years, but one that does not have the same significance so far as the number of workers is concerned, is diatomaceous earth pneumoconiosis. Legge and Rosencrantz²⁴ in 1932 reported silicosis in a high percentage of a sample in a California diatomite plant. Smart and Anderson²⁵ in 1952 reported the occurrence of a diffuse and relatively nonnodular pneumoconiosis in diatomaceous earth workers, with development of conglomerate lesions in advanced cases. They also reported that diatomite, which is converted to cristobalite by calcining, produced more severe and rapidly progressive changes than did natural amorphous diatomite. In 1953 and 1954 the Public Health Service conducted an epidemiologic study of diatomaceous earth pneumoconiosis in five diatomite plants in the Western States.²⁶

The abnormalities observed in chest films conformed in general with those described by Smart and Anderson, ranging from exaggerations of the bronchovascular pattern to massive confluent opacities. Associated with the linear exaggeration, which frequently extended to the periphery of the lung fields, there was often poorly defined, fuzzy nodulation. In many films the linear changes took the form of a fine reticulation, which could easily be called micronodulation; the radiologists found it impossible to distinguish consistently between the nodulation and fine interlacing linear changes. In all such cases the nodules were very small, and no cases were observed with discrete or well-defined opacities characteristic of quartz silicosis. In an appreciable number of films there were superimposed confluent shadows in the upper lobes, often bilateral, associated with evidence of em-

physema and in a few cases with gross distortion of the pulmonary structure.

Individuals whose employment was confined to quarrying had a definitely lower prevalence of abnormal films. The data indicated that quarry exposure did not produce definite linear-nodular or confluent changes. On the other hand, the findings confirm the hypothesis that exposure to cristobalite-containing diatomite, which is produced in calcining the natural product, is the major pulmonary hazard in the diatomite industry and that amorphous or natural diatomite is distinctly less hazardous. Adequate data are not yet available upon which to establish firm maximum allowable concentrations covering the different forms of diatomite. Present information, however, indicates that atmospheric exposure to diatomite containing over 5 per cent cristobalite should not exceed 5 mppcf. Similarly, atmospheric exposures to amorphous diatomite should be kept under 20 mppcf until data are available to define its biologic activity, including its effect upon superimposed infections.

New Environmental Developments

As new concepts are being developed on the pathogenic action of dust, progress is also being made in the environmental field. Even so, new instrumentation is needed for deeper probing into etiology of the pneumoconioses. The impinger and light field counting methods,⁴¹ although still useful as a standard, have outlived their usefulness as research tools. Many new instruments have been developed and others modified to meet special research needs. Despite this, however, none as yet has the versatility of the impinger. As an example, many variations of the thermal precipitator have been made in recent years including the oscillating type, and instruments with parallel plates and concentric tubes.⁴² Collection efficiencies of 99.9+ per cent for particles under one micron have been reported for the thermal precipitator as compared to a rather low efficiency for the impinger in this size range. Dust collection by use of impaction devices has been reported; an annular impactor developed for collecting and separating air-borne radioactive particles may find increasing application in collecting and classifying pneumoconiosis-producing dust.³³⁻³⁵

Development of the molecular membrane filter has revived interest in the filter method of dust sampling.³⁶⁻³⁸ Collection efficiencies appear to approach 100 per cent, and the size of the particle and its physical state are not altered in the collection process. Public Health Service research indicates that, if certain technical problems in manufacturing the membrane filter could

be solved, it would be very useful in dust evaluation.

A novel approach to the use of a filter for collecting aerosols is the concentrator principle,³⁹ by which the aerosol is collected on a rectangular screen in wedges of different thickness, varying in one direction so that it casts a shadow that is measured microscopically. Another approach to filtration is the creation of a stain on the filter by the aerosol which may be measured with a densitometer. The obvious disadvantage is that inaccurate results may be obtained with heterogeneous dusts.

Light field counting remains to be the most useful tool in dust evaluation, and the method is adaptable to samples collected by the molecular filter; however, greater reliance is being placed on statistical interpretation of the data. Much work on the statistical approach to the reliability of dust counts has been done by Chapman with use of the most-probable-number technique.^{40, 43} To overcome the difficulty in seeing particles, several new techniques have been devised, including phase contrast microscopy and the dispersion staining technique.⁴⁴ The latter procedure is also useful in determining free silica and other crystalline materials in the samples.^{45, 46}

More esoteric methods of dust counting involve the use of highly complex electronic equipment. Although these instruments have great potentialities, they are still laboratory curiosities for the industrial hygiene field. One instrument that utilizes television techniques as developed by the Radio Corporation of America for counting blood cells could be adapted to counting smaller dust particles.⁴⁵

Evaluation of dust conditions in the industrial environment would be greatly enhanced if instrumentation were available to make possible direct readings in the field. Of such instruments now available, none meets the test for portability, durability, and versatility that would be required of a field instrument. The need for a fairly homogeneous aerosol is a factor common to all the direct reading instruments. In those industries, however, where homogeneous dusts are likely to occur in any given work area, a direct reading instrument is useful.

Instruments typical of those described usually depend for their operation upon the phenomenon of light scattering by dust particles. Among these are a modified photometer⁴⁶ developed by the Public Health Service and the commercially available Sinclair photometer⁴⁷ and aerosolscope.⁴⁸

Other direct-counting instruments utilize the principle of the electrostatic charging of particles or an electrically heated filament where

the change in resistance is correlated with concentration and size.⁴⁹

The development and extensive use of the electron microscope have led to widening of particle size ranges that can be evaluated. Fraser⁵⁷ described the combination of the molecular membrane filter and the electron microscope as approaching the ultimate in dust collecting and counting. Electron microscope grids have also been incorporated into instruments such as the thermal precipitator, electrostatic precipitator, and cascade impactor with a fair degree of success.

Control Methods

Although advances are constantly being made in dust control, ventilation remains the fundamental method. Vast improvements have been made in air cleaning equipment.⁵⁰ Baghouses, utilizing filters of synthetic fibers, are highly efficient for removing aerosols as fine as 0.005 micron,⁵¹ and reverse-jet filtration has undergone some modification and improvement, with a subsequent increase in the efficiency of the air cleaning technique.⁵² New inverted-type collectors⁵³ are being introduced, in which the air follows a tortuous path through screens that permit the particles to be wetted by a water spray. The dust particle thus becomes the nucleus of a droplet whose mass is large compared with that of the particle and can then be easily removed by a centrifugal collector.

In mining operations several new techniques promise to reduce the ambient dust load. Water infusion of the ore body before drilling and blasting is finding limited application.⁵⁴ The use of fog guns that permeate the working area with a fine mist after blasting appears to be promising and economical in reducing the dust concentration.⁵⁵ Wetting agents are being used to some extent with the fog technique and with wet drills to assure better wetting and allaying of the dust.

The use of high frequency sound waves for dust control has also found increasing application in industry.⁵⁶ The efficiency of a sonic precipitator may be increased by raising the power input; theoretically, at least, there is no lower limit to the collectible size of the dust. Because of the adverse effects of high-frequency vibration on the worker the collector has definite limitations.

Conclusion

In their socioeconomic aspects the pneumoconioses continue to be a major occupational health problem in the United States. For the

appraisal of the relation between environmental exposure and body response, on the one hand, and for the design of adequate control measures, on the other, further knowledge must be developed. With the acquisition of this knowledge, together with improved reporting of the pneumoconioses, it should be possible in years to come to reduce significantly the occurrence of these diseases, and the ill health and burdensome costs attending them.

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Testing Laboratory Hoods—Evaluation of Design Changes and Periodic Performance Testing*

N. H. KETCHAM, M.S.

Development Department, Union Carbide Chemicals Company, Charleston, W. Va.

In recent years there have been marked improvements in the design of laboratory hoods, and a growing recognition and appreciation of the important role hoods play in the health and safety programs of laboratories. To a large extent, this has been the inevitable result of the use of increasingly hazardous materials in the laboratories. The cost of air conditioning and ventilating modern laboratory buildings has also been a factor in forcing realistic attention on the design and performance of laboratory hoods. The use of "single pass" air conditioning and ventilating systems, with no recirculation of work room air, requires that a carefully controlled and constant volume of air be continuously removed from the laboratory building. The hoods are the main means of removing this air, thus they are now being recognized as an essential part of the air conditioning and ventilation system.

Although the progress has been gratifying, there are still two fields of effort which need to be given more attention. One of these relates to bridging the gap between the engineer who designs the hoods, and the laboratory personnel who use them. Frequently the hood is not used in a manner to take full advantage of the protection it could provide. More will be said of this later. The other field which needs greater attention has to do with adjusting the hood for proper operation when it is first installed, and then following this with periodic testing and maintenance to keep it operating effectively. Not only does this serve to assure continued proper operation of the hood, but it is also an important and practical way of evaluating basic changes in design. In some cases, designs which show up well when a new type hood is being tested at the factory do not prove practical when the equipment is in actual service.

Much has been written about preventive maintenance of industrial equipment. Some authors have discussed preventive maintenance with particular respect to local exhaust venti-

lation systems. National Safety Council publications have emphasized that local exhaust ventilation systems are important safety devices, and have given information relating to the methods and instruments used for testing these systems^{1, 2}. However, there is still a definite need for stressing that laboratory hoods are a highly specialized type of local exhaust ventilation system, and that the testing and maintenance program for them should be tailored accordingly.

Testing Procedures

The most important characteristic for a successful testing and maintenance program for laboratory hoods is simplicity. Tests which would be suitable and necessary for a complete engineering study conducted at the factory are too time-consuming and too detailed to be useful for periodic performance testing of hoods in actual use in the laboratory. If the tests are too difficult, too detailed, or too time-consuming, the testing program probably will not be sustained over a period of time.

Usually the basic information required can be obtained by means of two simple tests. The first test consists of using an instrument such as a Velometer to measure the linear velocity of air through the hood face. A useful way of doing this is to close the sash until only about three to five square feet of opening is left. Velometer readings are then made in positions approximating equal-area locations in the open face. In a properly adjusted hood, the individual velocity readings from top to bottom and from side to side should all be in the same order of magnitude, preferably within 25% of each other. The average velocity multiplied by the square feet of open face gives the volume of air being withdrawn from the room, as cubic feet per minute. It is essential that this air volume remain constant from year to year, particularly if the hoods are in an air conditioned building.

In addition to tests of linear face velocity, simple smoke tests using small hand-operated smoke tubes will determine the character of the air movement, i.e. whether it is unidirectional or turbulent. By generating smoke at the hood

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face, particularly along the sides, and the bottom edge, the air movement as it enters the face can be made visible. Any unusual turbulence, which might result in air being "spilled" from the hood into the room will be quickly detected. Unusual turbulence may result from the design of the hood itself. However, it can also result from objects in the hood, or from drafts of air in the room blowing across the face. Both the Velometer and smoke tube tests would, of necessity, have to be conducted with the hood operating under actual use conditions. For example, some hoods may contain equipment using stirring devices operated by compressed air, or may contain a bank of burners or hot plates. Performance tests conducted without the stirrers in use, or without the burners or plates turned on, could give very misleading results.

Usually the above two simple tests are all that are required to test a new hood at the time it is installed and adjusted, and to test it periodically thereafter. In some cases, however, when the hood is known to be performing inadequately and the reason is not self-evident, even after the two initial tests have been applied, a larger volume of smoke generated from smoke bombs is useful. When blowers are mounted directly on top of the hood, (a practice to be avoided if at all possible) the use of smoke bombs will quickly locate leaks in the blower casing or in the part of the ductwork which is under positive pressure. Smoke bombs enable the direct observation of the flow of exhaust gas from the end of the discharge duct, and in some cases recirculation of the discharged air back into nearby windows or air intakes may be demonstrated. Smoke bombs with burning times of one minute or three minutes are usually used. They are available in types giving either yellow or white smoke.

Frequency of Testing

After the initial installation and adjusting of a new hood, the frequency with which it will need to be tested will vary widely, depending largely on the work being done in it. In our experience, some will need to be tested as often as monthly. Others need be checked only at yearly intervals. Until experience has been gained for any given hood, it is usually advantageous to test it at six-month intervals. In many cases, this will turn out to be about the right frequency. It will soon become apparent which ones need to be tested more frequently, and which ones can be checked yearly. It must be stressed, however, that the testing must be done on a periodic basis, in order to detect incipient failure

before it occurs. The tendency to wait until the users start to complain about the hood performance can lead to tragic results. Also, in modern air conditioned laboratories such delays are a costly false economy.

Prototype Hood

In order to illustrate some of the information this paper seeks to convey, some performance characteristics and design features of a prototype distillation hood to be installed in a new laboratory building will be used as an example. It should be emphasized that although a hood which has some unique design features is being used as an example, the experience which resulted in adopting these features was based on simple periodic testing of hoods in actual use in the Company laboratories. The type of hood used as an example is large enough to accommodate complete still systems of a research and development scale. Such hoods are commonly referred to as "walk-in" or "floor type", in contrast to the smaller "bench type" also used in laboratories. The principles of testing and maintenance are, however, essentially the same for both the "bench" and "floor" type hoods.

One of the prototype hoods is shown in Figure 1. It is characterized by several features which have been discussed in the literature in recent years, and some features which may have originated with us. It has an air foil across the leading edge of the floor, and sloped vertical edges with no corner posts. These features have

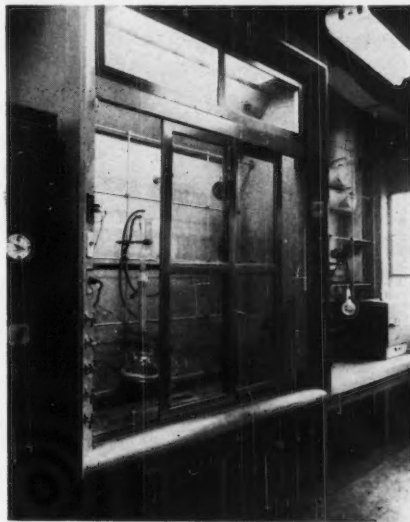


FIGURE 1. Prototype hood

been described in previous publications,^{3, 4, 5, 6, 7} and are now available in standard units offered by several manufacturers. The hood is elevated above the floor in the manner of a California type. However, our hood has a plenum with adjustable slots in the rear, two sides and a top, and only one open face, in contrast to the California type which is open on two sides. Our prototype hood features a horizontal sliding sash. This is an extremely valuable feature, in that it makes possible the use of a much lower volume of air flow than would be required for a hood of this size using a vertical sliding sash. The horizontal sliding sash also serves as an explosion shield and protects the user from splashes of toxic or corrosive liquids. There are two door segments which slide completely past each other and can be positioned anywhere along the face of the hood. With the door open to the maximum extent, the average face velocity through the opening is 60 linear feet per minute. Figure 2 shows a smoke test, with the door open to the maximum extent. The effect of the 60 feet per minute face velocity is clearly illustrated. With the doors in a maximum closed position, the average velocity through the center opening is 121 feet per minute.

Blocks at the end of the door channels keep the doors from completely closing at either end. Also, there is a slot under the air foil which is always open. Thus, as the doors cannot be completely closed, and as the blower is oper-



FIGURE 2. Smoke test with doors opened to maximum.

ated 24 hours a day, there are no "dead air" areas where combustible gases or vapors could accumulate.

From the point of view of the persons using the hood, it has several distinct advantages. The inside working height of 7½ feet makes it possible to contain complete still systems inside the hood. The glass panel across the top, above the sliding doors, enables thermometers or other measuring devices near the top of the still to be read from outside the hood. Fluorescent lighting is used in the top interior portion. A man can stand directly in front of the equipment in the hood, and can reach inside to adjust or work on the equipment, without placing his head inside. Not only is he protected from contaminated air, but by placing the sliding doors properly, he is also protected from an explosion originating in the hood.

The features of this hood which may be original with us evolved through a gradual process of design, testing, and use of a series of installations leading to the final selection. It is particularly important that many of the features were suggested by laboratory supervisors, and by the men who actually used or serviced the hoods. Recognition of some of the many persons who contributed to this work is given in the acknowledgments.

Resistance to Fires and Explosions

Figure 3 shows a similar hood, except that this one has three sliding door segments, and the entire structure sits directly on the floor. This hood has survived a moderate explosion and fire. It has been repainted and has had the glass replaced. Typical equipment in which highly toxic and flammable gases and liquids are being used, is seen inside the hood. Figure 4 shows it immediately after a fire and explosion. The sliding sash withstood the blast, and would have provided life-saving protection if a person had been standing in front of the hood at the time of the explosion. Although the resulting fire was quite hot, the safety glass and the motor and blower lasted long enough to confine the fire until it died down and could be extinguished. It was judged that if the fire had not been confined by the hood, it would have spread to the building itself and might very well have resulted in major damage. The fact that the blower continued running was a distinct advantage in this case. Had it failed, or had it been shut off, toxic gases, smoke, and vapors from the fire would have certainly required evacuation of the building.

Recording Data

The use of a suitable form for recording the results of the performance tests, and to keep a history of each hood, is most important. The use of a form makes the reporting and record keeping simple and rapid. Without a form, this becomes burdensome and time-consuming, to the extent that it may make the entire effort impractical. Each service group will tend to prefer a form of its own design. As an example, Figure 5 shows a form which has proven quite useful in one large laboratory.

The main body of the report provides space for a sketch of the hood face with the sashes in both an open and closed position. The results of velocity readings are recorded in the appropriate place, together with the dimensions of the face. The calculation of the volume of air being withdrawn from the room is shown on the form. Adequate space is provided for noting the results of smoke tests, and for making comments on the general conditions of the hood. This space is used to record maintenance and repair work done on the hood, or requested to be done. There is also provision made for recording the necessary identifying information and any miscellaneous information which might be needed for statistical purposes.

The primary value which is gained from these reports initially is, of course, to show whether or not the hoods are operating in the intended manner to protect the user. However, over a period of time, the reports also define the rate at which the hood performance is degenerating. This serves as the basis for deciding how often, and in many cases what kind of, preventive maintenance is needed.

Quite often the additional information which is recorded at the time the performance test is made will provide insight into the reason for the hood failure. This is important information, because it frequently distinguishes between failure due to the hood design, or for other reasons. For example, failure of the hood to perform in a satisfactory manner may be due to trouble in the exhaust duct, rather than in the hood itself. The trouble may be resulting from an improperly designed weather cap at the end of the exhaust duct, from an improperly designed duct, or from accumulation of dirt in the duct. The difficulty may be due to improper operation of the blower. If so, it is important to know whether the blower is failing due to accumulated dirt, or whether the impeller wheel may have been destroyed by corrosion. Sometimes electrical connections have been made incorrectly, with

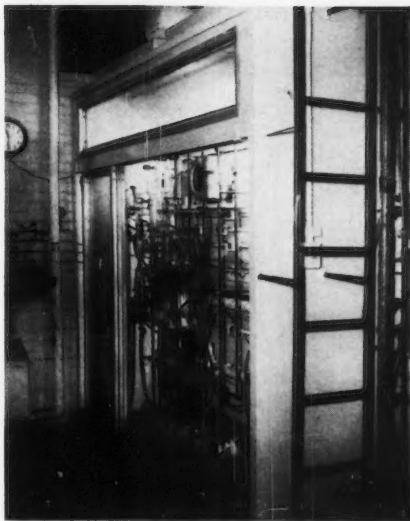


FIGURE 3. Floor type hood with three sliding doors.



FIGURE 4. After an explosion and fire the hood shown in Figure 3 looked like this.

the result that the blower is running backward. In many cases, the trouble may be due to drafts of air in the room usually from fans, supply air ducts, or open doors or windows.

FUME HOOD PERFORMANCE TEST

DATE: _____	BLOWER DESCRIPTION:	REPORT DISTRIBUTION
ROOM: _____	MOTOR HP: _____	COPIES TO:
BUILDING: _____	MOTOR RPM: _____	
TESTED BY: _____	TYPE BLOWER: _____	
	RATED CAPACITY: _____ CFM	
	AT _____ °F	

SASHES CLOSED		SASHES OPEN	
AREA 9.5 ft ² VOLUME 1145 CFM	AREA 19.3 ft ² VOLUME 1110 CFM	AREA 9.5 ft ² VOLUME 1145 CFM	AREA 19.3 ft ² VOLUME 1110 CFM
COMMENT: _____			

FIGURE 5. Form used to record data from hood performance tests.

Proper Use of Hood

There is still one field of effort which must be included in the total program if the desired service is to be obtained from the laboratory hoods. Even if they have been properly designed, properly installed and adjusted initially, and kept in good working order by means of periodic testing and maintenance, it is still necessary that they be used in the manner intended. A toxic contaminant originating at a distance from the hood face will not be adequately controlled. It is pertinent to add that toxic or objectionable liquids dumped in a sink across the room from the hood will not be controlled. If the contaminant is to be controlled, it must originate inside the hood. Also, the user must stay outside the hood, and this includes keeping his head outside. This may sound overly simple, but when working at a distillation hood equipped with the usual vertical sliding sash it is difficult to keep one's head outside.

The user should understand that the weakest part of the air flow pattern will be at the sides and the lower edge of the face. Even with an air foil along the front edge of the bench top, this may still be a weak point in the air flow pattern. Thus, sources of leaking gas or liquid should be kept as near the center and as far back from the front edge as is practical. When an extremely toxic liquid is being handled, it is desirable to provide a retainer to confine any spilled liquid, to keep it away from the extreme sides and front of the hood floor or table. Some

hoods, designed for handling radioactive materials, are provided with a front ledge to force the user to keep the hazardous material behind the ledge. The user should be aware that a hood adjusted for one kind of service may need to be readjusted when it is to be used on a different job. The proper use of the sashes invariably needs to be explained. Particularly, any new features, such as horizontal sliding sashes, should be explained so that they will be used in the manner intended.

Importance of Service Function

The responsibility for keeping laboratory hoods functioning in a satisfactory manner, and for advising the users of the proper way of using the hood, usually falls upon the laboratory service group. In larger laboratories this group is often a part of, and under the supervision of, the laboratory itself. In other situations, however, this group may be a part of some other maintenance department. Either way, one of the most important services the group provides is to keep the hoods performing in a satisfactory manner. Unfortunately, the importance of this work is not always fully appreciated.

The service group frequently exerts a much more profound influence on the ultimate design of laboratory hoods than is generally recognized. For example, in our experience laboratory service groups recognized the maintenance problems associated with "pressurized hoods" long before some engineers and manufacturers were fully aware of the serious nature of these problems. Service groups recognized hoods as an essential part of the laboratory ventilation and air conditioning system, long before this concept was generally recognized in the air conditioning and ventilation engineering literature. And last, but certainly not least, service groups have been among the first to recognize the false economy associated with failure to keep laboratory hoods operating effectively and efficiently.

Acknowledgments

Many persons employed by Union Carbide Chemicals Company made valuable contributions to the work upon which this paper is based. It would not be practical to mention all of these persons, although the author would like to do so. However, it is with great appreciation that the particular contributions of Mr. R. F. Hunt, Head of the Service Organization of the Development Department are acknowledged. In addition, Mr. E. W. Poinier, Jr., Works Chemist,

Institute Plant, and Mr. E. G. Despres, Head of the Design Practice Group, Engineering Department, made especially valuable contributions.

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CONFERENCE ON ELECTRONIC COMPUTATION

THE AMERICAN SOCIETY OF CIVIL ENGINEERS is planning to hold a two-day conference on structural applications of electronic computers. The meeting will be held in Kansas City, Missouri on November 20 and 21, 1958. The program is being designed to be of interest and value to persons just starting in the field as well as those more advanced by experience. Topics to be presented may include discussions of orientation and background, numerical methods, programming, coding, organization and selection, design problems, and new applications.

Inquiries should be addressed to Steven J. Fenves, Room 420, Civil Engineering Hall, University of Illinois, Urbana, Illinois.

HYGIENIC GUIDES AND BINDERS AVAILABLE

INDIVIDUAL HYGIENIC GUIDES in loose-leaf form may be obtained from the American Industrial Hygiene Association, 14125 Prevost, Detroit 27, Michigan, at 25¢ each. Discount of 20% allowed on orders of five or more; 40% on orders of 100 or more. Also available are flexible loose-leaf binders for the individual Hygienic Guide sheets. The binders have been especially designed to provide maximum protection and ease of handling of the Guides. They will be particularly useful in keeping a permanent file. The binders are blue in color, with white lettering, and are fitted with 3/4" rings. The price is \$1.25. The Guides and the binders may be ordered on the blank on page 351.

Lead-in-Air Analyzer

A specialized air sampling and analysis kit

T. DOWLING*, R. B. DAVIS*, R. C. CHARSHA†,
and A. L. LINCH†

E. I. du Pont de Nemours & Company (Inc.)

DEPENDABLE sampling equipment coupled with rapid analytical means is essential to industrial health control in the manufacturing and handling of toxic materials. The manufacture and handling of motor fuel anti-knock compounds containing tetraethyl lead are examples of industrial processes in which rigid control is especially necessary.

In 1948 a rapid micro-method for field use in determining the concentration of lead in air was described in *Analytical Chemistry*.¹ Since then, that method has been used successfully in all phases of the manufacture and industrial use of products containing tetraethyl lead. However, the determination of the concentration of lead in air remained an annoying and often arduous task, primarily because it was necessary to hand operate a vacuum pump while a four cubic foot sample of air was being drawn through a scrubber.

The successful adaptation of a special high efficiency micro-aspirator² powered by a "Freon-12"® propellant provides a simple, low-cost and effortless means of collecting and scrubbing the required large volume samples. Previously, many means of collecting samples had been tried in plant and field work, or evaluated in the laboratory. None of these means except the hand-operated pump met the requirements for general field use. Previous attempts to use liquefied gas were unsuccessful because no high efficiency micro-aspirator such as the "Uni-Jet"® was available.

A major requirement for a field unit is that it shall not be capable of igniting flammable or explosive vapors. The reason for this requirement is evident when it is realized that the principal use of the portable field unit has been in association with the cleaning and repairing of leaded gasoline storage tanks.^{3,4} Thus, the use

of the electric motor driven units or internal combustion driven units is unsatisfactory unless properly safeguarded. Suitable safeguards are often cumbersome and usually expensive. The sampling unit which is being described was tested for "static" generation when operating the "Uni-Jet" with "Freon-12" propellant. No response could be obtained when testing an insulated sampling unit with a grounded Keithly Electro-Meter, Model 210.

Another important requirement of a field unit is that it should be small and of light weight. The reason for this is that the technician collecting the sample must wear a positive-pressure or blower-type mask while inside the storage tank and therefore the technician should have his hands free so that he may readily manipulate the air supply hose. A small, light weight sampling unit will not interfere with the ability of the technician to make a thorough examination of the condition of the tank while the sample is being taken.

The successful adaptation of the "Uni-Jet" as a sampling means for a lead-in-air determination required certain modifications. The primary modification consisted in reducing the air sample from four to two cubic feet. As a result, certain changes in the quantities of reagents were necessary to maintain a direct reading in micrograms per cubic foot when using the existing Hellige color disc (Hellige No. 6205-10). The required quantities and a description of the reagents are tabulated in a latter section. Sealed reagents can be purchased professionally packaged and boxed. Each box contains a set which is sufficient for one lead determination. (Code 256-2 cubic feet, High Chemical Company, Philadelphia, Pa.)

Another modification was the replacement of the special scrubber described by Snyder et al.¹ with a midget impinger manufactured to rigid specifications, including close dimensional tolerances. These tolerances are indicated in Figure 1 showing the special midget impinger. Unless

* Operations Section, Petroleum Chemicals Division, Wilmington, Delaware.

† Medical Division, Industrial Hygiene Laboratory, Chambers Works, Penns Grove, New Jersey.

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these tolerances are maintained, it is impossible to predict the calibration of the sampling unit.

The efficiency of the midget impinger scrubber was tested in several ways: (1) A known atmosphere was sampled, using several types of scrubbers, and (2) An unknown atmosphere was sampled simultaneously while using several types of scrubbers. The results of the tests confirmed the fact that the midget impinger scrubber was at least equal to the scrubber described by Snyder et al.⁷

At this time, it appears that the components of a Jet Lead-in-Air Analyzer can be duplicated within a degree of tolerance which will permit the use of a standard calibration table. An example, Table I, has been prepared based on the results obtained in calibrating the sampling trains from eleven different analyzers. In this table, the "initial static vacuum" is shown. The static vacuum, or vacuum produced by the jet when no air is flowing, has been demonstrated by Charsha and Linch⁸ to be a measure of the efficiency and mechanical condition of the "Uni-Jet" aspirator.

Chart 1 shows the results of measuring the static vacuum on eleven aspirators from lead-in-air analyzers at several temperature conditions. Note that the gauge readings are within plus or minus $\frac{1}{2}$ inch of mercury of the curve representing the average.

Chart 2 shows the time required to draw a two cubic foot sample through eleven different sampling trains at room temperature with "Freon-12" at several different starting temperatures between 35 and 100°F. Note that the values are all within plus or minus two minutes of the curve representing the average.

Although this variation in time represents plus or minus 10 per cent, the error in the volume sampled was found to be only plus or minus 5 per cent. This relationship is derived from the reduction of propellant pressure which occurs as the "Freon-12" cools while the sample is being taken, and aspirations become less efficient toward the end of the sampling period. These results demonstrate the degree of reproducibility observed between the eleven units studied.

The time measured while drawing a two cubic foot sample through eleven different sampling trains at various temperatures between 30 and 100°F. when the "Freon-12" was at the same temperature as the surrounding atmosphere falls within a narrower range of deviation (Chart 3). This curve represents the usual conditions under which samples are collected. The calibration table was prepared from this chart.

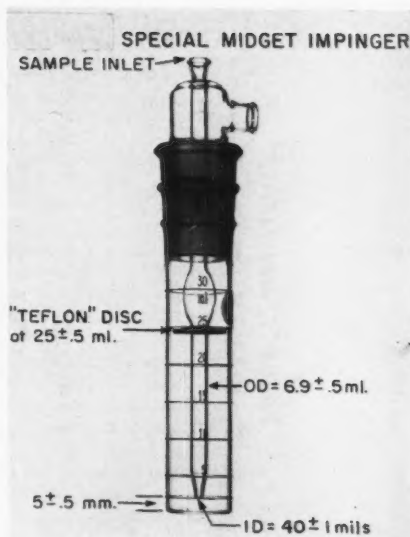


FIGURE 1. Special midget impinger

TABLE I
Calibration Data for Jet Lead-in-Air Analyzer

Observed Temperature °F.	Time Required for 2 cubic foot sample Minutes	Initial Static Test Vacuum Inches Hg.
100	12	6.0
95	13	5.5
90	14	5.1
85	15	4.8
80	16	4.4
75	17	4.1
70	17	3.8
65	18	3.5
60	19	3.1
55	19	2.8
50	20	2.6
45	21	2.4
40	22	2.1
35	23	1.9
30	24	1.6

Chart 4 compares the average curves shown in Chart 2 and Chart 3. It can be noted that the curves cross at about the temperature of the room in which the data shown in Chart 2 was obtained. When the ambient temperature is higher, more heat will be transmitted to the "Freon-12". The rise in propellant temperature increases the nozzle pressure and jet velocity which in turn increases the aspirating rate. By placing the two curves on the same chart, the results of this change in sampling rate are clearly shown.

Chart 1 "FREON" TEMPERATURE VS. STATIC VACUUM

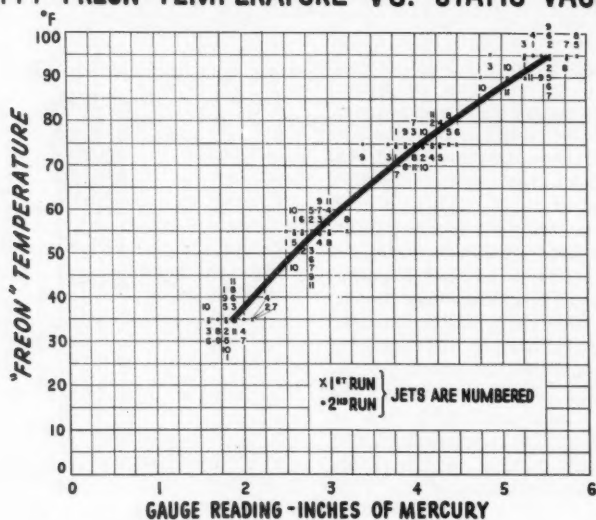


CHART 1

Chart 2 "FREON" TEMPERATURE VS. TIME REQUIRED

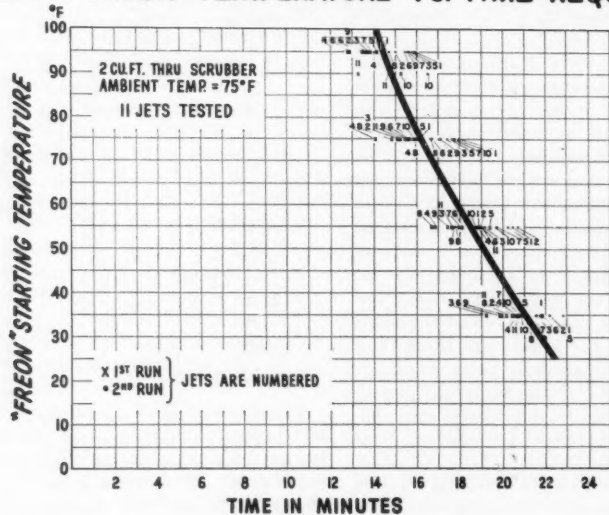


CHART 2

Description of Equipment and Reagents

The portable "Lead-in-Air Analyzer" which is shown in Figures 2 & 3 is housed inside an aluminum fitted case. The equipment is divided into two categories; that which is used in sam-

pling the air, and that which is used in determining the lead concentration.

The air sampling apparatus consists of a power assembly, aspirator, charcoal trap and scrubber. This apparatus is contained in a small metal case which is designed to be car-

Chart 3 TEMPERATURE VS. TIME REQUIRED

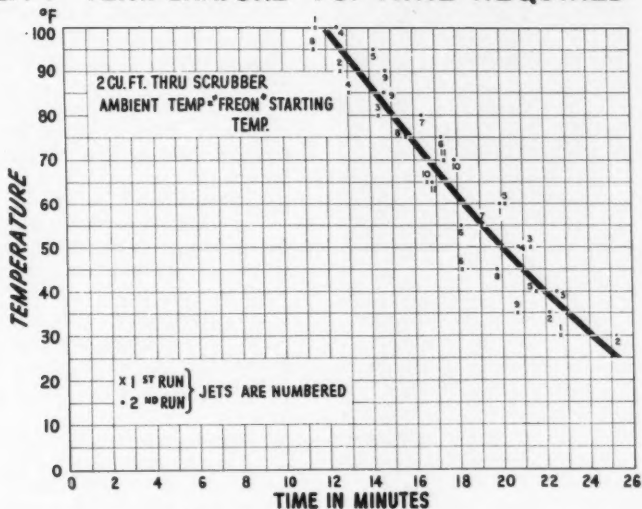


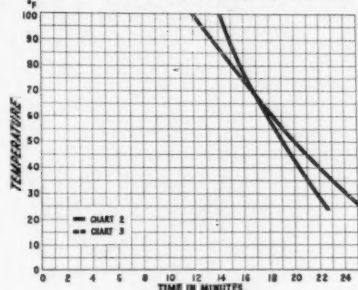
CHART 3

ried or to be worn on the safety harness while the air sample is being obtained. A thermometer, calibration chart and timer are also included. In addition, auxiliary or spare equipment is available consisting of a vacuum gauge, two spare scrubbers, three spare one-pound cans of "Freon-12" Power Pak Propellant and a spare charcoal trap.

The analysis apparatus consists of two comparator tubes, a Hellige Comparator, a "Deeminac" Water Purifier and 8 boxes of reagents. A "Deeminac" water purifier provides the equivalent of pure water. The filter holds the ionized impurities. It thus eliminates minerals and salts including chlorides. Each box of reagents contains sealed vials loaded with the exact amount of lead-free chemicals required for one determination. These chemicals are:

Quantity	Description ¹	
10 ml.	0.5 normal iodine	(A lead-free water solution of iodine and potassium iodide.)
15 ml.	Solution "A"	(A lead-free water solution of potassium cyanide, sodium sulfite, ammonium citrate and ammonium hydroxide.)
0.2 mg.	Dithizone	(Diphenylthiocarbazone)
5 ml.	Chloroform	

Chart 4. COMPARISON of CURVES for Chart 2 & Chart 3



Operating Lead-in-Air Analyzer

PREPARATION

Run blank tests to make certain that equipment is free of lead, and that wash water and reagents are satisfactory. Blanks are run in the same manner as samples except that collection of the air sample is omitted. If the equipment is known to be clean, and the reagents are known to be satisfactory, it is not necessary to run blanks.

In the event that you are unable to obtain a lead-free blank test, it will be necessary to de-lead the scrubber and comparator tube. Generally an iodine rinse, followed by several "pure"

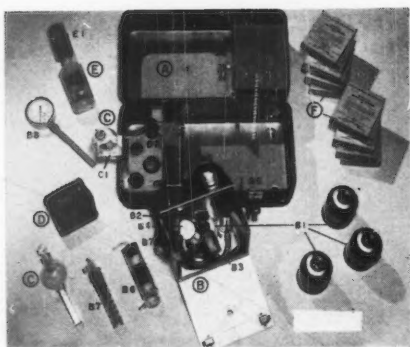


FIGURE 2. Portable Lead-in-Air Analyzer

A, carrying case; B, air sampling unit; B₁, "Freon-12" Power Pak propellant; B₂, valve; B₃, aspirator; B₄, thermometer; B₅, timer; B₆, charcoal trap; B₇, iodine scrubber; B₈, vacuum gauge; C, comparator tube; C₁, comparator tube holder; D, Hellige comparator; E, "Deeminae" water purifier; F, filter element; G, reagent packages. (Photograph courtesy of Union Industrial Equipment Company, White Plains, N. Y.)

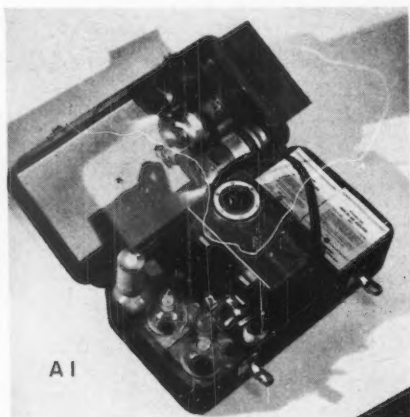


FIGURE 3. Complete Lead-in-Air Analyzer packed into special carrying case. (Photograph courtesy of Union Industrial Equipment Company, White Plains, N. Y.)

or distilled water washes, will be sufficient. If this fails, wash scrubber and tube thoroughly with warm dilute nitric acid, followed with sufficient "pure" or distilled water to remove all trace of the acid.

The purity of the water is critical. Water containing traces of impurities such as detergent, iron or chlorine may cause cloudiness in the chloroform layer.

A. Assemble power unit

1. Attach aspirator to valve:
 - a. Make sure that the nozzle (part F) and ring gasket (part E) are in place in aspirator body (part G).
 - b. Make certain lock nut (flat side against aspirator) is not tightened until after aspirator is finger tight against ring gasket. (Do not use wrench.)
2. Attach valve to "Power Pak Can":
 - a. Make sure that valve is open so that can will not be punctured by point of valve stem (part A) and that flat valve gasket (part K) is in place in valve body (part C).
 - b. Make certain that can lock nut (part J) is not tightened until after valve is tight against gasket. (Do not use wrench.) Hole is provided in lock nut as a safety vent.

B. Activate power unit

1. Close valve until point of valve stem touches can and then close about one additional full turn. This will cause point on valve stem to puncture can. Stem closes against metal of can. When valve is open the "Freon-12" flows from the can. One can contains sufficient "Freon-12" for two samples. A third sample may be erratic. (Caution: When removing valve from can after second sample, keep openings pointed away from eyes. Do not get liquid on anyone.)
2. Make certain valve stem packing nut (part B) is sufficiently tight to prevent leakage. Wrench should be used.

C. Test aspirator

1. Place can in sampling case and put thermometer in holder. Shake gently for about 30 seconds or until temperature reading is constant.
2. Connect vacuum gauge (part B₈ in Figure 2) to aspirator sampling connection (part H in Figure 4).
3. Open valve, read vacuum, then close valve and record vacuum. (This must be done rapidly and the maximum observed vacuum is the reading to be recorded.)
4. Compare vacuum reading with that shown on the calibration chart. If the reading is within 1/2 inch proceed with the sampling as detailed in the next section. If reading is not satisfactory (that is, the vacuum is not within 1/2 inch of that given in calibration chart) refer to section on Maintenance of Equipment.

PROCEDURE

A. To collect air sample

1. Charge the iodine scrubber with the contents of the iodine ampul. Snap ampul then invert and tap to empty iodine into scrubber.
2. Make certain that there is no liquid in the base of the charcoal trap.
3. Connect the scrubber train to the aspirator sampling connection (part H in Figure 4). Place inside small metal carrying case and install thermometer. (See Figure 5).
4. Read the temperature, determine the required operating time.
5. Open the valve, close the top of the sampling case, set the time to the required number of minutes, and obtain the sample. The timer is set by turning it counterclockwise to the indicated minutes. At the end of the time the bell will ring.
6. When the bell rings, discontinue sampling by closing the valve. (Note: The accuracy of the mechanical timer should be maintained by periodic checking.)

B. To analyze air sample

1. Disconnect iodine scrubber and warm iodine solution to at least 80°F. (This may be done by holding under a hot water tap, or by placing on a warm radiator.) Drain as much of the iodine as possible directly into the comparator tube. Add about 20 ml. of pure or distilled water to the iodine scrubber and wash remaining iodine into the comparator tube. The wash is repeated with an additional 20 ml. of pure or distilled water.
2. Add Solution "A" to comparator tube. Care should be taken not to allow any free iodine to remain around the neck of the comparator tube. Stopper the comparator tube and shake for about 3 seconds to permit Solution "A" to decolorize the iodine solution.
3. Pour the chloroform into the vial containing the dry dithizone and add this solution to the comparator tube. Vigorously shake the comparator for approximately 20 seconds and allow the two layers of liquid to separate. If the lower layer, chloroform solution, is colorless or of a slight greenish tint, there is no lead present. If the lower layer is red, orange, or orange red, lead is present.
4. If a red color is obtained (for orange or orange red see the following section) place the comparator tube in the Hellige Comparator and rotate disc on side until a color match is obtained. Read the lead concentration in upper right-hand corner in micrograms per cubic foot.



FIGURE 4. Power unit with exploded views of valve and aspirator assemblies.



FIGURE 5. Sampling train

Wash hands thoroughly when lead-in-air analyses are completed, as the chemical reagents are poisonous.

C. Conditions requiring new sample

1. Orange, or orange red color in chloroform layer—an incomplete reaction of the tetraethyl lead with the iodine is indicated. A new sample must be collected and analyzed, making sure that sufficient heat is applied, and/or enough time is allowed to permit complete reaction.
2. Color change from green to yellowish orange in chloroform layer—not sufficient sulfite present to reduce all of the iodine. Discard Solution "A". Make sure that Solution "A" used on new sample is fresh.
3. Water layer does not appear yellow—in-sufficient dithizone is indicated. The yellow color in the water layer is due to an excess of dithizone in the form of a soluble ammonium salt of dithizone. Test must be repeated.

Maintenance of Equipment

Proper maintenance of the apparatus, and fresh reagents are essential for good results. Keep the equipment clean and have on hand an ample supply of reagents. Reagents over nine months old should be destroyed.

The activated carbon charcoal trap is an absorption unit to remove corrosive iodine vapor from the air entering the aspirator. This trap should be replaced after approximately 50 samples have been collected. Make certain that the charcoal trap contains glass wool over the carbon to prevent particles from being drawn into the aspirator. A faulty trap may cause excessive resistance while taking the sample and could result in obtaining a sample of insufficient size.

The iodine scrubber is an efficient scrubber of a jet or impinger type. The "Teflon" (12) disc on the small tube extending into the liquid prevents an excessive carry-over of the iodine scrubber solution.

A. Calibrating the sampling apparatus—This is done by means of a dry test meter placed in the train between the aspirator and the charcoal trap. The vacuum gauge is connected between the meter and the aspirator (see Figure 6).

1. Read temperature after making certain that the thermometer is in contact with the can and that the temperature is stabilized.

2. Read static vacuum. Open valve, pinch rubber hose between gauge and meter and record maximum reading on gauge.

3. Measure the time required to take a sample (2 ft³). Two samples should be taken. The temperature of the can must become stabilized by returning to ambient temperature before it is used for the second sample. There should not be a variation of greater than two minutes between the time required for the two samples. The average time should be recorded.



FIGURE 6. Calibration equipment

A, Power Pak propellant; B, aspirator; C, thermometer; D, valve; E, vacuum; F, dry test meter; G, charcoal trap; H, iodine scrubber.

4. Prepare a calibration curve. Measure the temperature, static vacuum and average time for at least two and preferably four temperature conditions.

5. Prepare a calibration chart. Read and record time at each 5° temperature interval to the nearest whole minute. The calibration table shown in Table I was prepared from a curve made by using temperature conditions in which the "Freon-12" was at ambient or room temperature.

B. Trouble shooting—If static vacuum varies by more than ½ inch of Hg from that shown on the calibration chart the cause is probably:

1. Wrong temperature—shake unit and make certain temperature reading has stabilized.

2. Leakage of "Freon-12"

- a. Test all pressure connections with a thin soap and water solution using a small brush.

- b. Check position and condition of ring gasket between valve and aspirator. (All "Freon-12" must go through nozzle.)

3. Leakage of air

- a. Hold finger on both ports of aspirator and test connections with soap solution.

- b. Check condition of hose, position of stopper in charcoal trap, and fit of impinger tube in scrubber.

4. Pluggage

- a. Remove nozzle from aspirator body and blow "Freon-12" through the tip.

- b. Wash thoroughly with copious quantity of cleaning fluid such as acetone and dry before reinstalling.

Precautions

The accuracy and meaning of the results obtained with this instrument depend upon the skill and knowledge of the technician making use of it. A dangerous condition can be created by permitting anyone to use this instrument or interpret the results obtained by using the instrument in a manner which was not contemplated or intended.

The chemical reagents in the lead-in-air analyzer are poisonous and should be handled with care. They should not be left where children or anyone unfamiliar with their use can tamper with them. Wash hands thoroughly after handling.

The iodine solution will corrode metal surfaces as well as stain the skin or clothing. Care should be used to avoid spilling or contact. Stains on the fingers can be readily removed by wetting with Solution "A" and then washing thoroughly with water. Solution "A" may remove the color from dyed garments.

Uses of Lead-in-Air Analyzer

This paper would not be complete without providing further detail concerning the present field uses of the Lead-in-Air Analyzer as an aid in the continuing effort directed toward protecting workers from harm and injury.

A. Use in tank cleaning

The primary use of the lead-in-air analyzer is to aid in determining whether a tank that has been judged clean is lead-free. The use of the analyzer is a supplement to the visual inspection of the cleaned tank, and should be used only after all the other steps outlined below have been completed. It has been the practice of the industry to consider that a tank is free of the lead hazard when—

1. All sludge has been removed.
2. All non-adherent material from that portion of the tank that has been in direct contact with the sludge has been removed.
3. The tank has been swept dry of all liquid.
4. It has been ventilated until the concentration of lead in air is within safe limits (4 micrograms per cubic foot).

The above description applies to the lead hazard only, and is without regard to the explosive or other hazards that may be present. In addition, it must be emphasized that it applies only so long as the following precautions are observed:

1. Never take a lead-in-air analysis in a tank until items 1, 2 and 3 of the above description of a lead-free tank have been complied with.
2. Never declare a tank lead-free if any surfaces of the tank which have been in contact with the leaded material are to be heated above the normal temperature as with cutting, burning, welding, or steaming unless all iron rust, scale or other foreign material has been removed from areas to be heated.
3. Do not take samples for lead-in-air analysis for the purpose of declaring a tank lead-free while forced ventilation is being used, since an analysis at such time may not represent a true condition.
4. Never declare a tank lead-free if the tank contains absorbent materials such as wood or concrete.
5. Never declare a tank lead-free if there is any indication of a leaky bottom, even if the lead-in-air analysis, following visual inspection, indicates safe lead concentration.
6. Never enter a tank for the purpose of taking a lead-in-air analysis until the tank is gas free.
7. Remember that the results obtained by use of the analyzer are only a measure of the lead



FIGURE 7. Man dressed to protect himself during the collection of a sample from a "cleaned" tank that has been used for leaded gasoline.

concentration under specific conditions existing at the time the test is made.

B. Use in decontaminated areas

Lead-in-air analyzers may be used to determine whether an area involving a spill of TEL Compound has been properly decontaminated. A careful visual inspection of the decontaminated area must be made before using the lead-in-air analyzer. In general, the same precautions prevail for the use of the lead-in-air analyzer in buildings or open areas as exist for its use in connection with tank cleaning.

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What the ACGIH has done for Industrial Hygiene*

JOHN J. BLOOMFIELD

Regional Consultant in Industrial Hygiene, The Institute of Inter-American Affairs



John J. Bloomfield

John J. Bloomfield, more familiarly known to industrial hygienists as "Jack", was a pioneer in the development of industrial hygiene in the United States, and has been a leader and "sparkplug" in the field since those early days. He has transferred his pioneering and "sparkplugging" to South America, but continues to be a leader even here. This year, "Jack" was the recipient of the Cummings Memorial Award at the A.I.H.A. annual dinner. On the preceding evening, he was the honored guest and speaker at the Twentieth Anniversary Banquet of the American Conference of Governmental Industrial Hygienists. Your Editor and the Editorial Committee believe that the text of his talk at the A.C.G.I.H. dinner will be of interest and value to A.I.H.A. Journal readers for the historical background, and the ideas and concepts for the future.

SOME OF THE old-timers among us can probably remember that ACGIH meeting in 1948, which was held in Boston. At the last minute someone got the idea that it would be a good thing to have a banquet, and as I recall, we did have one at the Old Oyster House of the famous seafood. Of course, no banquet is com-

* Presented at the banquet of the ACGIH on the occasion of the 20th Anniversary meeting of this organization at Atlantic City, N.J., April 20-22, 1958.

plete without some formal entertainment, but since our treasury, as usual in those days, was very low, I was persuaded to furnish the entertainment in the form of an account of my adventures in South America, where I had spent nearly all of the previous year as a consultant for the Institute of Inter-American Affairs. As I recall that event, our treasury was so low that I even had to pay for my own dinner. Little did anyone of us think at the time that we were actually ten years of age.

With the exception of a few of the old guard who are here tonight, I don't suppose that very many people remember how the ACGIH got started, and how it grew to its present stature, and, believe me, it does have stature. I shall assume the prerogative of an anniversary speaker and turn the pages back for a few minutes to give you a little history of our organization and why it was created in the first place.

The ACGIH was really born of necessity. Prior to 1936, industrial hygiene activities in the United States were confined to research work, both in the laboratory and in the field, by the U.S. Public Health Service, the United States Bureau of Mines and one or two universities. Very little application of these findings was in practice in the States, because at that time there were only five States and one city engaged in official industrial hygiene work. In all probability, this limited work in industrial hygiene also accounted for the paucity of instruction in that branch of public health.

Now, as most of you know, the actual responsibility for safeguarding the health of our labor force rests chiefly upon State and local governments. In 1936, when funds were made available by the Social Security Act for the development and extension of all phases of public health work, the U.S. Public Health Service, in cooperation with the Conference of State and Provincial Health Authorities of North America, inaugurated a program designed to establish active industrial hygiene work in State and local health departments.

One of the most pressing problems presenting itself at that time in the development of industrial hygiene services in State and local govern-

ments was the lack of trained personnel to evaluate and control the then inevitable hazards associated with industrial work. The burden fell primarily upon the Public Health Service, because of its long experience in industrial hygiene work and its administration of social security funds for this purpose.

Realizing the urgency of the problem, and believing that some standard method of procedure should be set up for the guidance of industrial hygiene workers, the Public Health Service decided to give a short course of instruction to personnel selected by the various State health departments for work in this field. Accordingly, a four-week seminar was held during the summer of 1936, which consisted of lectures on industrial hygiene administration, health hazards, control methods, and similar subjects, as well as laboratory demonstrations of instruments used for investigative and control work. In the summer of 1937, a second seminar was held, since the number of persons engaged in industrial hygiene had increased from approximately forty to more than a hundred. Since these seminars could do no more than introduce the public health worker to industrial hygiene, additional training facilities were furnished by the Public Health Service. This training took the form of cooperative field investigations in various States. For example, studies were conducted in West Virginia, with the industrial hygiene personnel of that State, on the health of workers in the ceramic industry. Asbestosis was studied in North Carolina and South Carolina. The hazards in the hatters' fur carroting and felt hat industry were investigated in Connecticut, and, in 1939, three studies were conducted in cooperation with the Utah State Board of Health, on the problems in the metal and coal-mining industries, and in metal smelting and refining. Such studies served a dual purpose. The United States Public Health Service was fulfilling its function of conducting basic research, since these studies yielded information which could be applied on a national scale, and, at the same time, the State personnel had an opportunity to receive training in the practice of industrial hygiene and to make a good start in the evaluation and control of health hazards in the industries of the State in question.

During the last week of the second seminar in 1937, we came to the conclusion that we should continue these annual seminars but perhaps hold them under the auspices of a non-official organization, similar to the annual Conference of State Sanitary Engineers, which meets yearly with the Division of Sanitary Engineering of the United States Public Health Service. As a matter of

fact, in writing the constitution for the ACGIH, we used the constitution of the Conference of State Sanitary Engineers as a guide. An organization of this sort can very often accomplish things which an organization of a more official character is unable to do, because of certain limitations imposed upon official organizations. Two organizations which illustrate this point are the Conference of State & Territorial Health Officers, which is an official organization meeting with the Surgeon General of the Public Health Service every year by an act of Congress as in contrast to the non-official State and Provincial Health Authorities of North America. The latter very often makes statements and takes action on matters which the former would not dare to do, even though the same people are talking.

The first annual meeting of our Conference was held in Washington June 27-29, 1938. By that time, believe it or not, we had been able to organize twenty-eight industrial hygiene units throughout the various States and at the first meeting these units were represented by forty-three members, one associate, and six guests. The Executive Committee held its first meeting in my home, and that year the custom began of making the Executive Committee meeting, a dinner meeting, except that in this first year the dinner was held after the meeting at a well-known suburban restaurant known as "Mrs. Kay's Toll House Tavern." We had several drinks at my home following the meeting and those must have stimulated all of us to go "all out" on what we ordered, which as I remember, consisted mostly of what all good Americans like; beefsteak, baked potatoes, apple pie, and so on, washed down with sparkling Burgundy. When the bill appeared, it was passed on to me, since I had done all the arranging and was the secretary-treasurer. Much to my consternation, the bill was more than I could pay and then and there I instituted the custom, which I see still holds, of making the Conference pay for the dinner of the Executive Committee. In this particular instance, in order to pay the bill, I began collecting dues from the Executive Committee members and was just barely able to make out with what I collected and with the money I personally had in my pocket book. In those early days our treasury was always bare. As a matter of fact, even two years later, in 1940, the balance at the end of the year was only \$19.05, and so it went along for a good many years, until our Industrial Ventilation Committee put us in the "black". In reviewing the 1957 Transactions, I noted that the membership last year reached an all-time high of 374; (today it is more than

400) and that the Conference had a fat balance of six thousand three hundred and eighty-two dollars and seventy cents. Of course, the dollar is not worth today what it was twenty years ago, but even so, six thousand and some dollars is not "just hay".

With this much of a background on the early beginnings of our Conference, we might very well ask ourselves whether we, as an organization, have followed the road carved out for us by the founding fathers and what we have done with the heritage left us by the organizers of our association. The objectives of the Conference as set forth in the Constitution in 1938 and reaffirmed in the revised Constitution in 1951, tell us to go forth and "promote industrial hygiene in all its aspects and phases; to coordinate industrial hygiene activities . . . by official federal, State, local and territorial industrial hygiene agencies; to encourage the interchange of experience among industrial hygiene personnel in such official organizations; to collect and make accessible to all governmental industrial hygienists such information and data as may be of assistance to them in the proper fulfillment of their duties, . . ."

Now, just how did the Conference proceed to achieve the above objectives? And how well have we succeeded?

At the time the Conference was created twenty years ago, there had already been amassed a considerable backlog of valuable information concerning the health hazards associated with exposure to some of the classical occupational hazards and the means of controlling them. The spectacular radium dial painting cases had already been studied and regulations drawn up for the safe use of radium paint in industry. The classic studies of Leonard Greenburg on benzol poisoning in industry focussed our attention on this extremely useful but very dangerous solvent. Then, too, by that time we had behind us the investigations of the Division of Industrial Hygiene of the United States Public Health Service concerning the dusty trades and the Silicosis Conference which did so much to publicize the notoriously bad working conditions on some of our industries where silica and its compounds were encountered. The first reports on the results of the National Health Inventory were being issued about that time and these included the Occupational Morbidity and Mortality studies which the Industrial Hygiene Division of the Public Health Service had worked on.

The Conference had no more than begun to learn how to walk when, in 1940, it was obliged

to concern itself with the tremendous problems brought about by the defense effort which our country was making at that time. World War II taxed the energies of every organization and of every able bodied man and woman. Even before the "Day of Infamy", those of us in public health activities related to defense measures realized that the military had priority on manpower and for that reason it was up to the Public Health Service to jump into the breach with lease-lend equipment and personnel. At the height of the war, we had as many as seventy professional individuals on loan to the various States to help them carry on industrial hygiene work in the war effort.

The old maxim "It is an ill wind that does not blow some good" perhaps holds more truth for industrial hygiene than for many other activities. It seems almost axiomatic that national crises involving social and individual hardships and sacrifices often result in progress which would not have occurred otherwise, or at least would have been delayed. Industrial hygiene got its real beginnings in this country at the time of World War I and got off to a good start at the time of the depression which began in 1929 and which resulted in many social security benefits, including those for industrial hygiene and public health. World War II gave us the opportunity to demonstrate that our profession is here to stay. The obvious need for healthy manpower, and safe and healthy working conditions was our cup of tea, as they say in literary circles.

In looking back over the past two decades of the activities of our organization, we can really be proud of many of our accomplishments. Starting with practically no trained professional personnel we were able in a relatively brief period to muster several hundred persons who with a limited amount of training and experience could cope with the many problems inherent in our war effort. The war also gave us an opportunity to organize and develop industrial hygiene units where they had never before existed, so that by the end of the war we had in this country a network of such units established throughout the Union, in nearly every State, in large industrial cities and in several countries.

Now, I feel that we were able to accomplish all these things because from our very beginning we realized that our real strength as official agencies lay not in large numbers but in our ability to work uniformly and as a team, that we had to operate among forty-eight States, each perhaps with different legal requirements as to industrial hygiene practices.

From the very beginning of our organization,

we realized that one of the major functions of our group was the development of standard practices among the various units. For that reason, even during the first year we organized various standing committees to deal with problems of administration, such as those concerning professional qualifications of industrial hygiene personnel, which were very useful in giving our people status within the Merit Systems which were then being developed in the States. It was in those days too that the Committee on Threshold Limits began to function and, as all of you know today, this very important work has resulted in the annual review and publication of limits of several hundred toxic substances with which the industrial hygienist has to deal in his daily work. The work of this committee has been recognized by the publication of its finding annually and their use throughout the world. The general industrial hygiene code developed by the Committee on Uniform Codes as well as those covering special exposures, or industrial processes, have also achieved national status. Other accomplishments of this character deal with such subjects as standard methods of analysis, instrumentation, the uniform reporting of industrial hygiene activities and the uniform collection of occupational disease reports. Perhaps the most outstanding accomplishment of the Conference resulted from its Committee on Industrial Ventilation, which won the first award of the Conference for its outstanding work. To say nothing of the fact that the fruits of the committee's work—the Manual of Industrial Ventilation—has put our group on a sound financial basis. Other accomplishments of the Conference have resulted in the development of standard labelling procedures and uniform administrative practices, such as the promotion of small plant health services, uniform records and reports in industry and workers' health information. Today our standing committees are concerned with such additional problems as agricultural health, air pollution, the epidemiology of occupational diseases, and ionizing radiation.

In this manner I think we did a pretty good job of achieving the objectives of the Conference with respect to the coordination of industrial hygiene activities, with the collection and dissemination of information, and through our annual meetings we were able to encourage the interchange of our experiences. Our various committees and the results of their work filled a vacuum, since the ACGIH was the first to gather the mass of data needed.

I also believe that our Conference, made up as it is of a variety of public health workers, has

demonstrated that industrial hygiene is not the exclusive monopoly of any one profession but requires, for its successful application, the collaboration of various public health specialists, such as physicians, engineers, chemists, nurses, physicists, and others. Each of these has a specialized function to perform, but essentially they work as a team, each contributing his skill to the study of the hazard and its eventual control. This team approach has been one of the major contributions of the United States to the advancement of industrial hygiene as we know it today.

So much for the credit side. If I were to list anything at all on the debit side, it would be perhaps to mention that the State and local industrial hygiene units do not appear to be as strong and as vigorous as they were at the end of the war. Undoubtedly, this is due to two facts: we have lost many persons from the States to industry, and the various branches of the Defense Department, such as the Army, the Navy and the Air Force, have now developed their own industrial hygiene services. Many of the industrial hygienists among the latter originally came from the civilian agencies. The Atomic Energy Commission also has drawn heavily upon Conference members. The emphasis on air pollution control with the creation of special commissions or authorities to handle this problem has also been a drain on the State and local industrial hygiene units. This is all to the good for the industrial hygiene movement, but has considerably weakened the State and local hygiene work. I think this Conference with the cooperation of the United States Public Health Service should accept the responsibility for strengthening the various State and local units in industrial hygiene and should develop a program so that we can once again have strong and dynamic agencies giving services to industry.

I also seem to sense a trend to deviate a bit from the original charter laid down for us by the founding fathers in the nature of our annual programs. Quite early in the life of our association, we realized that in order to keep the Conference meetings from becoming just another reunion of a professional society and also to keep it within the organizational objectives of an official organization meeting to discuss mutual problems with the United States Public Health Service, it was necessary to set aside time for a conference with the staff of the Division of Industrial Hygiene of the Public Health Service. In this manner the Sunday pre-conference program developed, which consists in concurrent sessions of physicians, nurses, chemists,

and engineers who meet to discuss technical problems in their respective fields, and then the night session at which administrative discussions are held to iron out problems of legislation, salaries, relationship with other governmental agencies, and so on. In this way we could sort of let our hair down (those of us who had hair) or, to put it in another way, we could wash our dirty linen in private. I am very pleased to see that these pre-conference sessions on Sunday are still a useful and highly successful item on our annual agenda.

However, there is still the tendency to devote anywhere from one to one-and-a-half days of our limited annual meeting time to the presentation of strictly scientific papers, which I think would be better received at the AIHA or Industrial Physicians' sessions, thus giving our Conference more time for the discussion of solutions to some pressing administrative problems.

From this brief review of the history, early struggles and accomplishments of the Conference over the past two decades, it is evident that we, as an association, although small in numbers by comparison with other organizations of this type, have made an important impact on the industrial hygiene of our country. We may very well ask ourselves at this point what should be our role today and in the immediate future in these rapidly changing times? And they are changing, particularly in attitudes and concepts on the part of our clientele, that is management and labor.

Twenty years is such a short time, that it is easy for me to recall the attitude of management toward industrial hygiene and toward us as protagonists of this discipline. I can very well remember that as a member of the United States Public Health Service and without legal authority to enter industrial plants, I had a hard time convincing industrialists to cooperate in our investigations of health hazards. I still remember a very amusing incident that happened to me during the time when we were studying the hazards associated with sandblasting. I called on one factory in Connecticut and tried to persuade the owner to let me come there and study certain sandblast operations which I was anxious to add to the data we were collecting. He was very dubious about letting me come in and take some samples of air, saying that he was suspicious of any scientific studies and of so-called scientists. Finally, after a considerable sales talk on my part, he said:

"Well, all right, young man. You can come here and do these studies; but, you must come yourself. I don't want any of these college boys coming around here!"

The same difficulties but from a different viewpoint were experienced with labor. Organized labor had had its troubles with management in that from time to time a worker was fired, or not hired, on supposedly health grounds, when sometimes it was due to the fact that a particular worker was considered undesirable because of his union activities. Obviously, with management taking such an attitude, labor fought the physical examination, since it felt that at times it was not used for the purpose intended, that is to assess a man's physical condition and to place him in the job he was physically and mentally qualified to perform.

I can recall the time when labor contracts specifically stated that the physical examination would not be pre-requisite to employment. As a result of such a labor attitude, management was at times forced to employ disabled persons who could not be properly placed because of a lack of information on their health status. There were cases of epileptics working on ship construction in places where they were a danger to their fellow workers and to themselves. Many of our early investigations were made difficult for us because of the time wasted in trying to convince labor to submit voluntarily to a physical examination, which we needed in our studies of the relationship between health and working conditions.

I should like to relate one little incident to illustrate the suspicious feeling which prevailed between management and labor in these early times. One day I was inspecting a metal mine in the Far West in connection with one of our silicosis investigations. My guide, the superintendent of the mine, and myself had stopped in one of the levels in the mine to rest a bit and to smoke a cigaret. The level below us was very near; so close that we could hear a couple of miners talking. As near as I recall the conversation between the two miners, it went something like this:

"Say, Bill, what do you think of this notice the company put up, that every man that has worked for a year will receive ten silver dollars as a bonus for Christmas?"

The second miner replied, "Well, I'll tell you, Fred. I'm a bit suspicious of all this. I just can't picture the company giving anything away for nothing. And you mark my words, we are going to pay for this one way or another!"

Well, these times have changed for the better, and we as a group certainly played a part in bringing about the changes. To understand the new viewpoint of management, one only has to pick up the annual Transactions of the Industrial Hygiene Foundation. In 1935, twenty

companies met for the first time to organize an association to combat silicosis. Today, this organization of industrialists can count over four hundred in its memberships, and its annual meetings are a bright star in the industrial hygiene constellation. Although this organization still continues to give services to members on some of the older problems in our field, such as the classic occupational diseases, in late years it also has concerned itself with such important problems as noise, atmospheric pollution, radiant energy, sickness insurance, mental health, social security, the older worker in industry, the impact of automation on health, and the general field of labor and management relationships. Management realizes only too well that if it does not show as much concern for the men who operate machines as it does for those very machines, it will not realize the full potential of the new technology.

Labor also, has come of age and is showing a greater concern for social security for its workers and now considers this as but an extension of its traditional preoccupation with wages and hours and working conditions. That is why we find today many health and welfare programs written into collective bargaining contracts. Recent studies made by the United States Public Health Service show that practically every major union in the country had negotiated to some extent pensions, or health and welfare provisions, for their members. Labor too, has now endorsed the physical examination as a prerequisite to employment and job placement, recognizing that in the long run it is a benefit to the worker and not something to be feared.

In view of these changing concepts in occupational health on the part of both management and labor, we might very well ask ourselves whether or not our role as government officials has changed in any way. To begin with, I think we should bear in mind that although management has assumed greater responsibility than ever before in occupational health, and although labor now realizes that it has much to gain in co-operating more fully in occupational health programs, the role of the government industrial hygienists has far from lessened but has actually increased, and will continue to grow.

It is true that many of the large industries have developed their own industrial hygiene programs, but we still have with us the smaller plants where the bulk of the labor force is employed. These smaller plants—and some of them are not so small—still look to us for guidance in the solution of their health problems. And even the larger industries need our help in assuming their newer responsibilities, such as in

the fields of total coverage medical care plans, retirement provisions, the problem of the older worker and rehabilitation. Also, some of the older occupational disease problems are still with us and to these we may add the new ones, such as air pollution and the insecticides. Then there are the problems posed by the ever increasing use of radioactive substances in industry.

In order to make use of the available resources to the utmost, we should begin to consider seriously a plan to integrate administratively the means at our disposal which exist within our local health departments, the small plants, and certain governmental agencies with a stake in the industrial hygiene claim. Instead of just striving for a peaceful co-existence with local health departments and our sister governmental agencies, we should study ways and means to integrate our work in such a manner that we can present a united front and in this way render better and more adequate services, and perhaps really begin to make a dent in the perennial problem of the small plant. I am confident that with the right approach you will receive a real welcome and a will to work in a cooperative manner on the part of these groups.

It should be quite obvious from this brief look at the future that our Conference has a tremendous job ahead of it and we must prepare ourselves to meet the demands which industry will be making for our services. I suppose too, that we must be prepared to continue losing some of our best personnel to industry unless we make an earnest drive to make government jobs really attractive, and I do not mean just from the viewpoint of take-home pay alone. I know that many of the State jobs pay very poorly and, to make things even worse, have very inadequate retirement plans. One of the reasons the United States Public Health Service has been able to hold on to many of its officers has been the provision of a career service with fairly adequate salaries and excellent social security benefits, including retirement pay and medical care for dependents. I am all for having the Conference appoint a standing committee with some dynamic individuals on it who will develop a plan of action to solve this problem of a career service for our State and local industrial hygiene personnel.

As you know, I have come some four thousand miles to be with you all and to take a backward look at our Conference to see what we have accomplished and what the future holds for us. It is not all so backward either, since we were only striplings when World War II sneaked up on us and put us to the test. You are just now

growing a good beard and have acquired the responsibilities which go with that adornment. Your influence has gone beyond the United States, since, as you know, several of your colleagues are now working in Latin America. We now have about twelve countries south of the Rio Grande which boast of modern industrial hygiene programs, comparable to any of those in

our own country. There is much to be accomplished in those countries, since they are only now beginning to industrialize and to experience the problems which faced us some twenty years ago when this Conference got its start. Perhaps that is one of the reasons why I find my work in Latin America so satisfying, for I can truly say, "This is where I came in".

Nuclear Insurance and Standards*

R. G. McALLISTER

Liberty Mutual Insurance Company, Hopkinton, Massachusetts

WHEN RADIOISOTOPES were released for civilian use shortly after the end of World War II, the safety engineers and industrial hygienists employed by casualty insurance companies found themselves faced with the problem of evaluating radiation hazards in laboratories, research facilities and factories, in steadily increasing numbers. Protection of the health of men working with ionizing radiation was not new to these men; the use of x-ray machines and radium capsules to make radiographs and gamma-graphs of welds and castings for the purpose of detecting structural flaws had existed for many years. But, the vast expansion of the radiation protection problems that accompanied the rapidly accelerating distribution of radioisotopes during the early post war period, and the entry of private industry into such fields as research for development of improved nuclear fuels, routine reactor fuel element fabrication, preparation of "tagged" compounds, and the multiplicity of other uses found for radioisotopes, presented a control task of an infinitely greater magnitude.

The urgent need for a safety code for the industrial use of x-rays and radium that arose during the war years as use of non-destructive inspection rapidly expanded due to rigid standards of manufacturing for vital parts of military equipment was met, somewhat belatedly, by the American War Standards, ASA Z54.1—1946, "Safety Code For The Industrial Use Of X-Rays". This safety code was a, "Consensus of the best rules and specifications for preventing accidents in the industrial use of x-rays and radium." Formation of the code was requested by the Division of Labor Standards, U.S. Department of Labor, after consultation with the National Bureau of Standards. Representation on the committee was wide, including various federal government bureaus and departments, and military branches, state health departments, private industry, hospitals and universities. The concern of the casualty insurance companies with radiation safety standards at that time was

indicated, I think, by the fact that there was representation from three casualty insurance companies on the parent committee.

Speaking from personal experience, I can say that Z54.1 has served both industry and casualty insurance companies well. A "Class A" installation, as defined by this ASA Code, incorporated a physical arrangement that provided a very high degree of safety, and if management followed the code recommendations for education and supervision of radiographers, the risk of excessive exposure was minimal. When an insurance safety engineer or industrial hygienist reported to his underwriting department that a policyholder had an x-ray installation that conformed to the ASA Z54.1 Class A, B, or C requirements, it meant something specific and was of great help to the underwriters in evaluating risks.

The ASA Z54 Code went for several years without revision and became obsolete in at least one respect, the maximum permissible dose rate to external ionizing radiation. The Code is currently under revision and later will be published in its up-to-date form.

Radiation protection codes have not been available for the majority of the ionizing radiation problems that have been demanding our time and attention in the past four or five years. Though the permissible limits of exposure to external radiation and maximum permissible concentrations in air and water of most of the isotopes of interest are given more or less satisfactorily in *NBS Handbooks 59 and 52*, and in Title 10, Part 20 of the *Code of Federal Regulations*, there is a disconcerting lack of agreement on many details of radiation protection programs among the health physicists best qualified to express their views on the subject. This includes the health physicists responsible for radiation protection in various AEC installations. It is very evident that standardization is needed in such aspects of radiation protection as dosimetry and monitoring methods, reporting of surveys, keeping of records, and waste disposal, to mention but a few.

One particular phase of the exploitation of

* Presented at the American Industrial Hygiene Association annual meeting in Atlantic City, N. J., April, 1958.

nuclear energy where lack of standards has been felt keenly by the casualty insurance companies is in the safe design and construction of reactors. Dr. C. R. Williams reported on this in his paper, "Factors Affecting the Insurability of Nuclear Reactors," which was read in the Symposium of the Peaceful Uses of Atomic Energy at the International Conference held under the auspices of the United Nations at Geneva, Switzerland, in August of 1955. The following is taken from his paper: "The Atomic Energy Act of 1954, at the same time that it made fuels for nuclear reactors available to American private enterprise, placed full responsibility for all liability for damage resulting from reactor operations upon industry. When industry started to examine its potential liabilities in connection with construction and operation of nuclear reactors, many of the groups interested in participating in the reactor program felt that their potential liability might in some cases exceed their resources. Some of the individual corporations and groups associated for development of nuclear power began to explore the possibilities of obtaining from insurance companies the liability coverage which they considered necessary. The extremely high limits requested by private industry could not be provided by individual insurance companies. There are legal limitations imposed on insurance carriers relative to liability limits on a single risk. If such had not been the case, the very high liability limits requested were, in most cases, beyond the financial resources of any one company."

There were other reasons that the insurance industry was reluctant to provide liability coverage on nuclear reactors: it had little knowledge of what it was being asked to cover; at that time the entire private reactor program was, in fact, experimental; and there was no assurance provided as to the development of standards of construction and operation of reactors. No specific approval and inspection program had been set up.

The American insurance industry was able to meet this demand to provide liability coverage, only by forming pools in which each company agreed to furnish coverage in accordance with its financial resources. The stock companies formed two pools called, Nuclear Energy Liability Insurance Association (NELIA) and Nuclear Energy Property Insurance Association (NEPIA). The mutual companies formed the Mutual Atomic Energy Reinsurance Pool (MAERP). To further expand the pool resources, foreign underwriters were invited to participate. The total capacity of all the pools and the foreign underwriters amounted to \$125,000,000.00. This

capacity, the largest ever assembled in American insurance history, is split, \$65,000,000 for physical damage insurance and \$60,000,000 for third party liability insurance. The amount of public liability insurance considered essential by corporations and associated groups was far in excess of this amount. This need has been met by the Federal Atomic Energy Indemnity Act, in the form of an amendment to the Atomic Energy Act of 1954, passed by Congress in September, 1957 (Price-Anderson Bill). It gives an upper limit of \$500,000,000 for aggregate indemnity in connection with each nuclear incident, in excess of \$60,000,000 third party liability.

The question may be asked, "Why do we need standards for the nuclear energy field, when we have the *NBS Handbooks*, 10-CFR-20 and some state codes, with more coming." Quoting Admiral W. A. Kitts, "The difference between standards and codes on one hand, and laws and regulations on the other, is essentially that standards and codes are primarily voluntarily accepted documents, not imposed and are prepared usually as the result of a consensus by those most affected by their use. Laws and regulations are drawn up by a legislative body and imposed and administered by inspection authorities. They are related only in that good standards may lead to the development of good laws."

Fortunately, some individual, or group of individuals, in American Standards Association decided to do something about the lack of standards in the field of nuclear energy. The result was a conference—a general conference on National Standardization in the Field of Nuclear Energy—held in Washington, D.C. on December 8, 1955. This conference was attended by all those interested in nuclear energy, and was called by authority of the Standards Council of ASA. It was attended by over 175 individuals representing over 100 organizations, which is indicative of the broad backing received.

The conference unanimously approved the idea that standards in the field of nuclear energy should be handled in accordance with the time-honored American custom of following the procedures of the ASA in obtaining a national consensus of standards consistent with the purposes, philosophy and membership of ASA in its role as national clearing house for standards. In a meeting of the Steering Committee of the Planning Committee on *Standardization in the Field of Nuclear Energy* held at ASA headquarters on March 15, 1956, it was voted to recommend the formation of an American Standards Association Nuclear Standards Board for the purpose of supervising the development of standards for the nuclear energy field. The members of this Board

represent various technical associations and societies, labor organizations, governmental organizations and bureaus, and private industries. The insurance industry has as members on N.S.B. Dr. Charles R. Williams and Mr. Reuel C. Stratton, who represent the National Association of Mutual Casualty Companies and Association of Casualty and Surety Companies, respectively.

At the first meeting of the Nuclear Standards Board on September 18, 1956, it was voted to set up five projects on:

1. General and administrative standards for nuclear energy.
2. Nuclear instruments.
3. Electrical requirements for reactors and nuclear power systems, and for generation and application of nuclear radiation.
4. Chemical engineering for the nuclear field.
5. Reactor hazards.

At this meeting it was voted to invite various organizations to sponsor the several projects. At a later meeting of N.S.B. another project was added: development of standards for radiation protection. It was decided to organize ASA Sectional Committees to write the standards according to tried and tested ASA procedure.

ASA NUCLEAR STANDARDS BOARD SECTIONAL COMMITTEES, SCOPES AND SPONSORS:

N-2, General and Administrative Standards for Nuclear Energy

Sponsor: Atomic Industrial Forum

Chairman: William A. McAdams

Secretary: Saul J. Harris

Scope: Standards, specifications, and methods of administration associated with the peaceful use of nuclear energy including color codes, symbols, nomenclature, qualifications of professionals, records and reporting systems and procedures, and accountability of materials.

N-3, Nuclear Instruments

Sponsor: Institute of Radio Engineers

Chairman: William H. Hamilton

Secretary: L. G. Cumming

Proposed Scope: Standards, specifications and methods of testing for instruments used in the nuclear field including instruments for personnel protection, reactor control, industrial processes, analysis and laboratory work, radiation calibration equipment and components therefor.

N-4, Electrical Requirements for Reactors and

Nuclear Power Systems and Generation and Application of Nuclear Radiation

Sponsors: American Institute of Electrical Engineers

Electric Light and Power Group

National Electrical Manufacturers Association

Chairman: Philip N. Ross

Secretary: Richard W. Shaul

Proposed Scope: Standards, specifications and methods of testing for the electrical equipment used in nuclear reactors and nuclear power systems and in the generation and application of nuclear radiation.

N-5, Chemical Engineering for the Nuclear Field

Sponsor: American Institute of Chemical Engineers

Chairman: Stanley I. Winde

Vice Chairman: Wheaton W. Kraft

Scope: Standards, specifications, tolerances, and methods of testing on the chemical engineering aspects of the nuclear field including: the refining, processing, separation, purification, treatment, packaging, handling, and disposal of fuels and allied materials such as radioisotopes, industrial chemicals, pharmaceuticals with isotope tracers, and radioactive wastes (gases, liquids, and solids); the use of radioactive sources for tracer purposes and for processing of foods and other materials; and the application and use of chemically resistant coatings and the cleaning of contaminated equipment and facilities.

N-6, Reactor Safety Standards

Sponsors: American Nuclear Society

American Society of Mechanical Engineers

Chairman: Alfred Iddles

Vice Chairmen: Harold Etherington

Miles C. Leverett

Secretary: Melvin Ross

Scope: Codes and standards concerned with the hazards involved in the design, location, construction, and operation of nuclear reactors and of potential critical assemblies.

N-7, Radiation Protection

Sponsors: Atomic Industrial Forum
National Safety Council

Chairman: Remus G. McAllister

Vice Chairman: Hugh F. Henry

Secretary: Saul J. Harris

Scope: Safety standards for the protection of persons employed in facilities associated with the production and utilization of fissionable

materials against the normal, routine hazards present in such facilities (facilities include mines, mills, refineries, separation plants, fuel element fabrication plants, critical assembly facilities, processing and reprocessing plants, working areas around nuclear reactors of all types, and transportation, and purification of "spent fuel elements" and gross fission products).

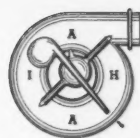
Obviously, these committees must work with any other ASA committee, the N.B.S., N.C.R.P., I.C.R.P., A.E.C., and each other, to avoid duplication of effort and conflicting standards. The work is in its early stages so not many conflicts

of interest have developed. Those that have were resolved with little difficulty.

As Chairman of the N-7 Committee, I have every confidence that the need for nationally and internationally accepted standards will be met in the next year or so. It is sometimes slow work to get agreement on certain phases of standardization for the nuclear energy field but with the wide backing indicated by the 1955 meeting in Washington, agreement will be reached. The insurance industry has a considerable stake in seeing that standards are developed and are determined to contribute its share to the undertaking.

INDUSTRIAL HYGIENE POSITIONS

THE EXECUTIVE Secretary of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION maintains a list of positions in the field of industrial hygiene. Prospective employers and those seeking employment in industrial hygiene are encouraged to make use of this service. Inquiry should be directed to GEORGE CLAYTON, Executive Secretary, AIHA. 14125 Prevost, Detroit 27, Michigan.



HYGIENIC GUIDE SERIES

Bromine

I. Hygienic Standards

- A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): One part per million parts of air, by volume (ppm).¹ This value may be too high (See Short Exposure Tolerance below).

(1) *Basis for Recommendation:* Irritant properties to eyes and respiratory tract.

B. SEVERITY OF HAZARDS:

(1) *Health:* High, for acute; moderate, for chronic exposures. The effects are primarily irritation of mucous membranes from vapor contact, and deep surface burns with brown discoloration of the skin from liquid contact. Rashes, especially of the face, may occur with bromine inhalation or bromide ingestion.

(2) *Fire:* None. It does not burn but is corrosive and generates heat of reaction.

- C. SHORT EXPOSURE TOLERANCE: Undisturbed work is possible when the concentration is 0.15 to 0.3 parts per million, and impossible at 0.6 parts per million.² Lacrimation occurs below one part per million and levels of 10 parts per million or above cause such severe upper respiratory irritation that such concentrations will not be voluntarily borne.⁴

- D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: For humans, forty to sixty parts per million is dangerous for short exposure, and 1,000 parts per million is rapidly fatal upon short exposure.³

II. Significant Properties⁴

A reddish brown liquid and vapor with a sharp, penetrating, irritating odor.

Chemical symbol: Br₂

Molecular weight: 160

Boiling point: 59° C at 760 mm Hg

Vapor pressure: 175 mm Hg at 21° C

Specific gravity (liquid):

3.12 at 15° C

Relative vapor density:

5.5 (air = 1)

Solubility:

In water, and most common organic solvents.

At 25° C and 760 mm Hg,

1 ppm of vapor:

0.0065 mg/liter

1 mg/liter of vapor:

153 ppm

III. Industrial Hygiene Practice

- A. RECOGNITION: May be recognized by its color, odor, and irritant effects. Major uses are in the manufacture of fumigants, dyestuffs, drugs, bromides, and brominated hydrocarbons.

B. EVALUATION OF EXPOSURES:

(1) *Direct instrumentation:* None. Electrical conductivity or pH measurements, following collection in water, may be made.

(2) *Chemical:* Collection in o-tolidine and estimation by colorimetry or spectrophotometry.²

- C. RECOMMENDED CONTROL MEASURES: Maintain workroom atmosphere below 1 ppm by means of ventilation and enclosure of processes. Personal protective equipment may be necessary.

IV. Specific Procedures

- A. FIRST AID: Remove from exposure. Thoroughly wash all contaminated surfaces with mild soap and water. Irrigate the eyes with water for at least 15 minutes.

- B. SPECIFIC MEDICAL PROCEDURES: None, except in placement; aggravation of chronic pulmonary disease should be considered.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health*, 16: 261 (1957).
2. ELKINS, H. B.: *Chemistry of Industrial Toxicology*. John Wiley and Sons, Inc. New York (1950).
3. HENDERSON, Y., and HAGGARD, H. W.:

Noxious Gases. Reinhold Publishing Corp., New York (1943).

4. Manufacturing Chemists' Association, Inc.: *Chemical Safety Data Sheet SD-49, Bromine*. Washington, D. C. (1952).
5. PATTY, F. A. (Editor): *Industrial Hygiene and Toxicology, Vol. II*. Interscience Publishers, Inc., New York (1949).

Hydrogen Chloride

I. Hygienic Standards

- A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 5 parts per million parts of air, by volume (ppm).¹
 - (1) *Basis for Recommendation*: Sensory response.²
- B. SEVERITY OF HAZARDS:
 - (1) *Health*: Moderate, for acute exposure; low, for chronic. The effects are primarily irritation of upper respiratory passages. Higher concentrations result in eye irritation, and fatal lung injury has been reported from single massive exposures.⁴ Erosion of the teeth may occur in persons who work regularly in atmospheres containing hydrogen chloride.
 - (2) *Fire*: None.
- C. SHORT EXPOSURE TOLERANCE: 50 parts per million parts of air.³
- D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: 1000 to 2000 parts per million parts of air.³

II. Significant Properties

Hydrogen chloride is a gas, highly irritating to the nose and throat.

Chemical formula:	HCl
Molecular weight:	36.5
Boiling point:	-83.7° C
Relative vapor density:	1.26 (air = 1)
Solubility:	Water: 82.3 gm per 100 ml of water at 0° C
At 25° C and 760 mm Hg,	
1 ppm of gas:	0.00149 mg/liter
1 mg/liter of gas:	670 ppm

III. Industrial Hygiene Practice

- A. RECOGNITION:
 - (1) Used chiefly as a water solution (hydrochloric acid) containing 38% or less of hydrogen chloride.
 - (2) By its irritant action on the respiratory passages.
- B. EVALUATION OF EXPOSURES:
 - (1) *Instrumentation*: Collection in water and measurement of electrical conductivity.
 - (2) *Chemical*: Collection in water or alkaline solution, and determination of either the acid or the chloride content by acidimetry or titration, respectively. Nephelometry, using silver nitrate, may also be used.²
- C. RECOMMENDED CONTROL MEASURES: Maintain workroom atmosphere below 5 parts per million parts of air or concentration which causes significant irritation. Protect skin and eyes from contact.

IV. Specific Procedures

- A. FIRST AID: If hydrochloric acid is spilled on the skin, the affected part should be immediately flushed with clean water. Eyes, if affected, should be irrigated for at least 15 minutes.
- B. SPECIAL MEDICAL PROCEDURES: None.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. Ind. Health*, 16: 261 (1957).
2. ELKINS, H. B.: *Chemistry of Industrial Toxicology*. John Wiley & Sons, Inc., New York (1950).
3. HENDERSON, Y. and HAGGARD, H. W.: *Noxious Gases*. Reinhold Publishing Corp., New York (1943).
4. THIELE, E.: *Zentralbl. Arbeitsmed u. Arbeitsschutz*, 3: 146 (1953). Abstract in *JAMA*, 154: 631 (1954).

Because of space limitations, it is impossible to list all methods of exposure evaluation. The selections have been made on the basis of current usage, reliability, and applicability to the usual industrial type of exposure. Any specific evaluation and/or control problem will involve professional judgment. This can best be done by professional industrial hygiene personnel.

Respiratory protective devices are commercially available. Their use, however, should be confined to emergency or intermittent exposures and not relied upon as primary means of hazard control.

A relative scale is used for rating the severity of hazards: nil, low, moderate, high, and extra hazardous.

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News of Local Sections

Chicago

Officers for the 1958-59 year are: President, Paul J. Whitaker, M.D., Allis-Chalmers Mfg. Co., Milwaukee, Wisconsin; President-Elect, Paul D. Halley, Standard Oil Company of Indiana; Secretary-Treasurer, George P. Bittner, Inland Steel Company.

Our last spring meeting was held April 2nd. Sheldon Bennett, M.D., Dermatologist, discussed particularly the sensitizing nature of certain materials used in the plastics manufacturing industry. Color slides showing the severity of some cases were impressive.

Northeastern Ohio

Officers for the 1958-59 year are: Chairman, Lou Beliczky; Vice-Chairman, Howard Lorton; Secretary-Treasurer, Harold C. Cutter.

At our meeting on April 9th, Mr. Donald T. Green and Mr. Joseph B. Stickney of the Picker X-Ray Corporation discussed radiation hazards, their control and instrumentation. Special invitations to this meeting were extended to industrial radiographers and isotope users.

Western New York

On Friday, May 23, 1958, Herbert I. Miller, Jr. extended the hospitality of Bethlehem Steel Company's Lackawanna Plant to the Western New York Section. Members of the association

were invited to bring guests, and members of the Industrial Medical Association were also invited. About 40 people turned out for an extremely interesting and educational tour of the nation's third largest steel plant. Following the tour, the group was served luncheon at the Lackawanna Hotel and was addressed by Dr. J. M. Dziob, Plant Surgeon of the Lackawanna Plant.

Upper Midwest Section

This spanking new Section had its organizational meeting on June 17, 1958 with 20 people attending, all of whom joined the Section. The officers elected at this meeting are as follows: President, George S. Michaelsen, University Health Service, University of Minnesota; President-Elect, Ralph C. Wands, Minnesota Mining and Manufacturing Company; Secretary-Treasurer, Harold J. Paulus, School of Public Health, University of Minnesota; Elective Directors, Dr. L. W. Foker, Northwest Industrial Clinic, Minneapolis, and George M. Reed, Honeywell.

Following the business meeting a short film on the testing of detergents was shown. Mr. George Michaelsen then discussed the industrial hygiene problems associated with a university. We expect to more than double our present membership in the first full year.

Attention Secretaries

Secretaries and other officers of all local sections of A.I.H.A. are urged to submit news of meetings and other items of interest from their Sections and areas. The *News of Local Sections* can be only as interesting and worthwhile as the news which you supply. Send items to Lloyd Gordon, Room 500, 135 South La Salle, Chicago 3, Illinois or to the Editor at Cincinnati.

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